The TREND

IN ENGINEERING

at the University of Washington

In this issue:

- Cosmic Ray Tracks Studied at Lofty Site
- Olivine: A Foundry Sand Aggregate
- Production of Ozone with Refrigerated Anodes
- Studies of the Thin Film by Electron Diffraction
- High-Frequency Losses in Electric Conduit
- Slip of Structural Steel Double-Lap Joints with High-Strength Bolts
- Importance of Engineering Research to Education

July, 1951

VOL. 3, No. 3

Aristotle Speaks for the Physicist

THE SCIENCE OF NATURE is concerned with spatial magnitudes and motion and time, and each of these at least is necessarily infinite or finite. . . . Hence it is incumbent on the person who specializes in physics to discuss the infinite and to inquire whether there *is* such a thing or not, and if there is, *what* it is. . . .

"Some as the Pythagoreans and Plato, make the infinite a principle in the sense of a self-subsistent substance, and not a mere attribute of some other thing. . . . The physicists, on the other hand, all of them, always regard the infinite as an attribute of a substance which is different from it and belongs to the class of the so-called elements—water or air or what is intermediate between them. Those who make them limited in number never make them infinite in amount. But those who make the elements infinite in number, as Anaxagoras and Democritus . . . say that the infinite is continuous by contact—compounded of the homogeneous parts . . . [Anaxagoras], or of the seed mass of the atomic shapes . . . [Democritus].

"Further, Anaxagoras held that any part is a mixture in the same way as the All, on the ground of the observed fact that anything comes out of anything. For it is probably for this reason that he maintains that once upon a time all things were together . . . Democritus . . . asserts the contrary, namely that no element arises from another element. Nevertheless, for him, the common body is a source of all things, differing from part to part in size and in shape.

"It is clear then . . . that the inquiry [regarding the infinite] concerns the physicist. Nor is it without reason that they all make it a principle or source."

—Aristotle (384-322 B.C.), *Physica*. From *The Student's Oxford Aristotle*, W. D. Ross, ed., Oxford Uni. Press, 1942.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;
(2) to undertake extended research and to publish reports on engineering and scientific problems;
(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

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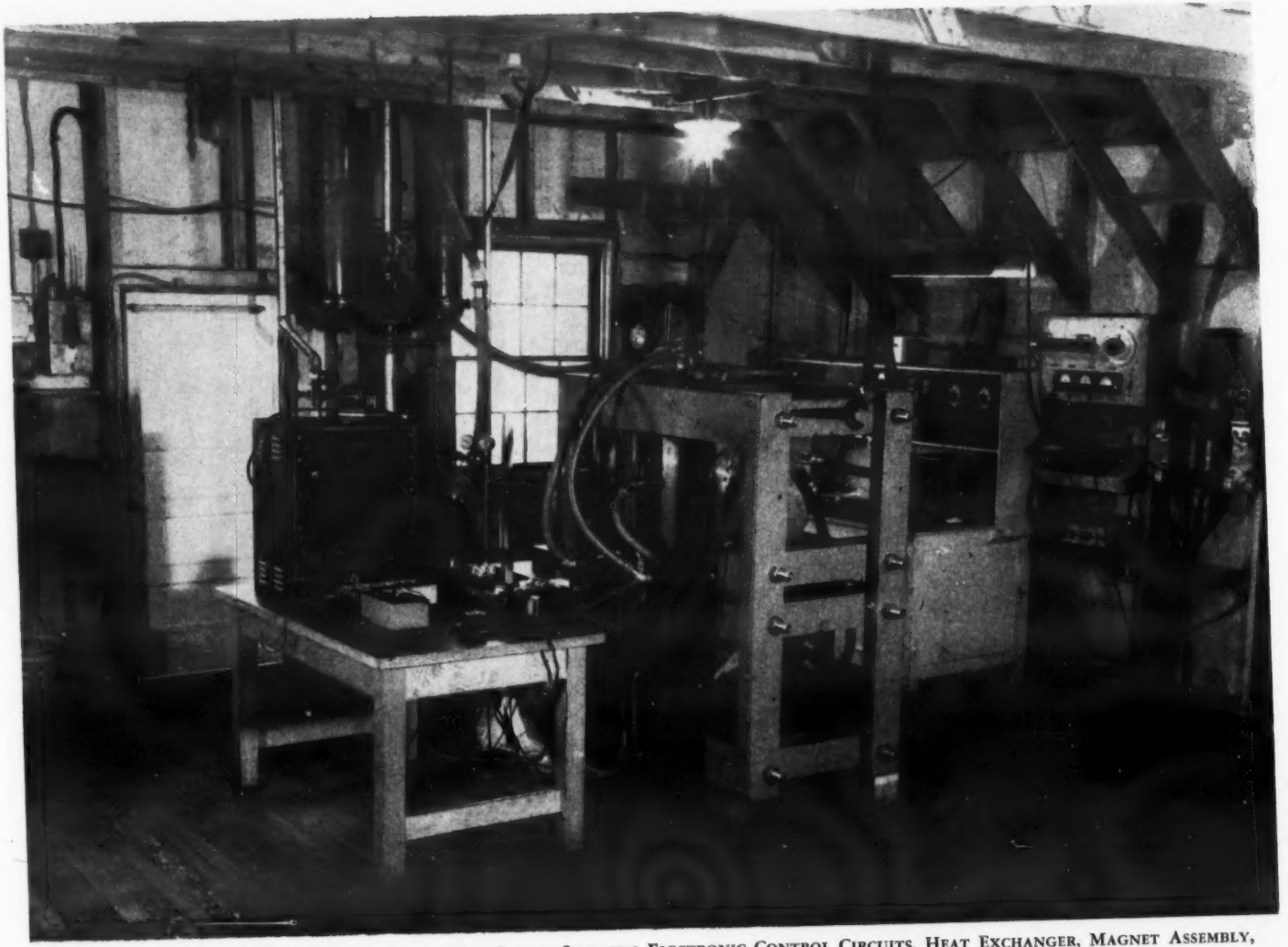
COVER

H. C. Maynard, machinist *(left)*, and Dr. C. E. Miller, Assistant Director of the Applied Physics Laboratory, assembling one of the four magnets, used in the cosmic ray investigation, into its case.



PRELIMINARY LABORATORY SETUP FOR COSMIC RAY STUDY, SHOWING ELECTRONIC CONTROL CIRCUITS, HEAT EXCHANGER, MAGNET ASSEMBLY, AND GENERATOR CONTROL ASSEMBLY

FREMONT PASS: SITE OF U. OF W. COSMIC RAY TESTS NEAR CLIMAX, COLORADO

Cosmic Ray Tracks Studied at Lofty Field Site

C. E. MILLER
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D. S. POTTER
Project Physicist

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Junior Physicist

FOR A GENERATION NOW, physicists the world over have devoted much labor and ingenuity to a study apparently remote from any technological application. Incident on the earth from outer space are particles known as cosmic rays. These particles represent an energy source equal only to that of star light falling on the earth. Even though the total energy is small, it is concentrated in a small number of very energetic packets and appears as a slow rain of nuclear particles. Early studies in the field showed only the existence of some extraterrestrial source of atmospheric ionization. More recent and vastly more elaborate quantitative investigations have identified the type of particles concerned and shown something of the way in which they react with the matter through which they pass. The over-all phenomenon is one of vast complexity. Today the radiation that first enters the earth's atmosphere is believed to consist mostly of energetic protons, protons with energies as high as a hundred trillion electron volts. Recent investigations, initiated by the Universities of Minnesota and Rochester, have revealed also the presence, in small numbers, of the nuclei of heavier elements, mostly below iron, though even the nuclei of the very heavy elements are occasionally found. Thus cosmic rays consist of just those elementary particles which constitute ordinary matter but stripped of electrons and moving through space with velocities closely approaching that of light. A complex chain of events is initiated when these projectiles enter the atmosphere and shatter those atoms of nitrogen and oxygen with which they chance to collide. Simultaneously there are created, in a manner not wholly understood, new types of radioactively unstable particles. These particles and their decay products, as well as the nuclear fragments of the original collisions, in turn produce secondary and tertiary generations of particles of many types. Experimental study of these naturally occurring events of which our senses tell us nothing can truly be said to constitute the most advanced frontier of present day experimental physics. It is in just this realm of extremely high energy that the conceptual background

C. E. Miller

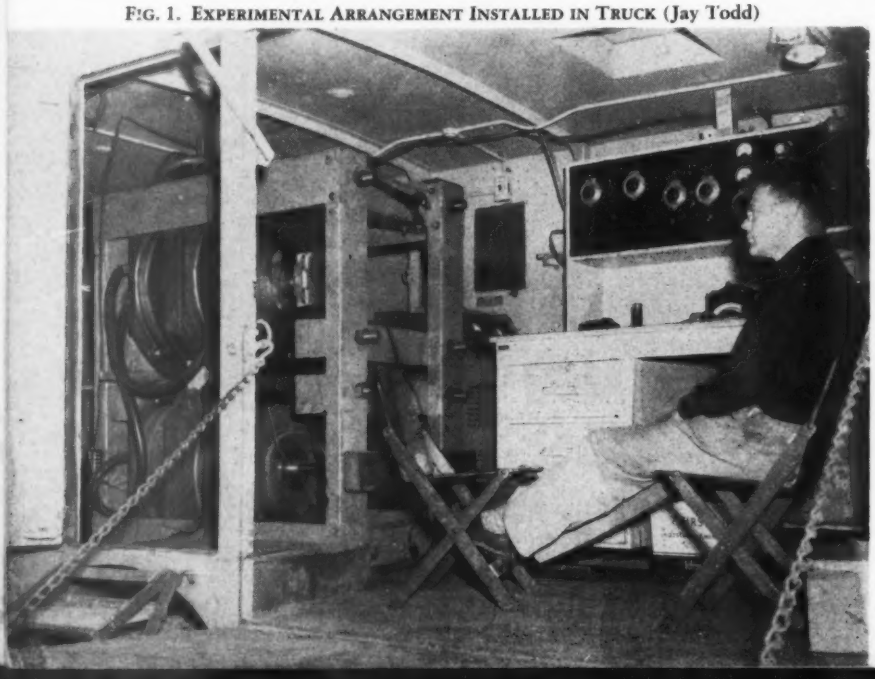
of theoretical physics is able to correlate only partially current theory with what we observe. The attempts to evolve a theoretical treatment of these phenomena will lead to the physical science of the future.

Experimentally, long periods of preparation and prolonged series of observations are necessary to unravel even a small feature from the over-all cosmic ray phenomenon. In sharpening his tools to observe these effects in detail the cosmic ray physicist has evolved many of the techniques used today in nuclear physics and nuclear engineering. These techniques of corpuscular physics represent an important contribution to present day technology. From the standpoint of the physicist the study has been rich in new discoveries. It was in this field that Anderson discovered the positron; Anderson, Neddermeyer, Blackett, Powell, and others, the various types of mesons; and Rossi and other investigators, the magnificent phenomenon known as cascade showers. One has the feeling that no cosmic ray effect can be carefully studied without leading ultimately to some new and unexpected result. A frequent observation is that of a very high energy particle which passes through the equipment used revealing only its presence, but giving no indication as to its nature or energy. Laboratory magnets used to deflect particles of lower energy produce no measurable effect on these. No practical thickness of lead will slow them down noticeably. Here the physicist resorts to the earth as a laboratory. By going deep under ground he can measure the absorption produced through great thicknesses of matter. By comparing observations at widely separated latitudes he uses the magnetic field of the earth, which extends thousands of miles into space, to observe magnetic deflections he is unable to produce in the laboratory. Observations from balloons, rockets, aircraft, and mountain laboratories reveal the nature of the radiation before it has penetrated deeply into the earth's atmosphere. The first rocket to the moon will certainly carry cosmic ray equipment telemetering its findings back to earth. It may well be that human travel beyond the atmosphere may be limited by the dangerous biological effects of the more intense radiation.

D. S. Potter

Starting about five years ago the Applied Physics Laboratory of the University of Washington, a division of the Department of Physics, initiated a program of cosmic ray study. This study was supported in its early stages by the Bureau of Ordnance, Navy Department, and later by the joint program of the Office of Naval Research and the Atomic Energy Commission. Participating in the program have been Professor Joseph E. Henderson, Director of the Laboratory, the present authors, and a number of graduate students from physics, chemistry, and electrical engineering. Among the latter for a period was Mr. Elwood Stewart who worked under a grant from the Engineering Experiment Station and was responsible for some of the initial work on the pulsed electronic circuits used for cloud-chamber control. The contributions of the technicians and machinists who have worked on the project have also aided greatly in its success. Indeed, careful engineering and construction have been necessary throughout in order that the tons of elaborate equipment could be transported from Seattle high into the Colorado mountains and operate continuously for months without failure.

FIG. 1. EXPERIMENTAL ARRANGEMENT INSTALLED IN TRUCK (Jay Todd)



To date the efforts of the laboratory have been largely devoted to a systematic study of the detailed composition of the cosmic radiation at sea level and at mountain altitudes. The technique centers around two Wilson cloud chambers and associated magnets. By operating the chambers in a magnetic field of

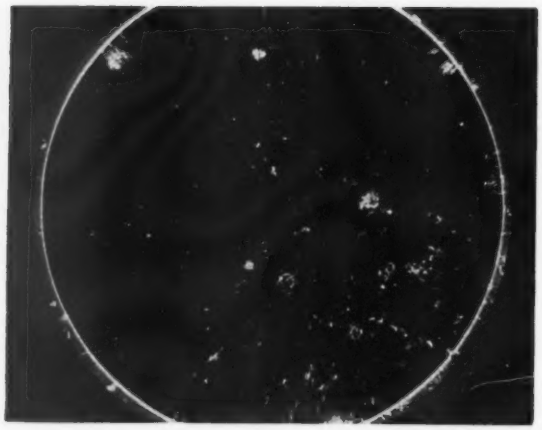
Jay Todd

around 10,000 gauss directed perpendicular to the direction of traversal of the charged particles, the particles are bent to give curved trajectories. Measurement of this curvature on the photographs taken of the cloud tracks (Fig. 3) gives the energy of the particle producing the track up to energies of about two billion electron volts. The field is not strong enough to deflect appreciably more energetic particles. The photograph on the cover shows one of four similar magnet windings which were constructed. With the very efficient and high-velocity oil circulation used for cooling, current densities as high as 7,000 amperes per square inch in the copper can be used. In our studies, random pictures of particle tracks are not of great interest; therefore, an arrangement of geiger counters and associated electronic circuits selectively photographs events of particular interest. These are arranged so that only tracks of particles passing through specified counters and not through others are photographed. For example, the equipment can be arranged so as to photograph those cosmic ray particles which (1) pass through the cloud chamber, (2) are not accompanied by other particles, (3) penetrate five centimeters of lead after passing through the chamber, and (4) do not penetrate an additional ten centimeters of lead. All operations necessary to the functioning of the equipment and recording of data are carried through automatically. These operations, too numerous to mention, are performed by various transducers, servo-mechanisms, scaling circuits, and other elements. Something over a hundred vacuum tubes are required to perform all these functions. Laboratory tests of the equipment were run shortly after its completion in 1947. The experimental arrangement is shown in the frontispiece, page 4. Many modifications have since been made.

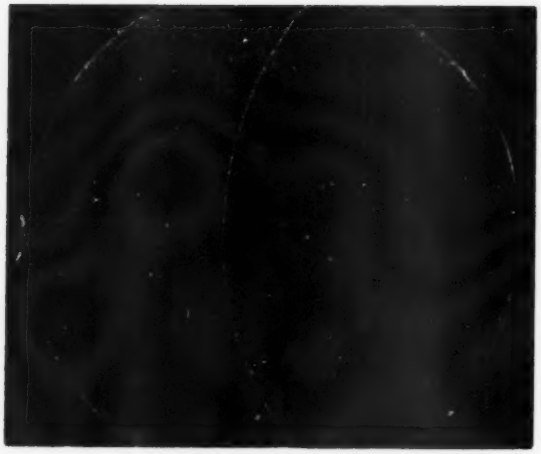
Since 1948 the group has spent several months each summer high in the Colorado mountains. Magnets, generators, etc., are operated on the trucks in which they are transported (Figs. 1 and 2). Fortunately it has been possible to operate on the grounds of the Climax Molybdenum Company at Fremont Pass. The pass, at an elevation of 11,300 feet, is accessible the year round on good roads. The mining company has provided electrical power, cooling water, and comfortable living quarters for the crew. The work would not have been possible except for the generous cooperation of Mr. J. C. Abrams, Mr. Robert Monett, and other personnel of the Molybdenum Company.

Perhaps the most remarkable instrument in the whole field of corpuscular physics is the Wilson cloud chamber. In our own work we have taken some seventy-five thousand pictures of cloud tracks and still find it interesting to examine a new set of pictures. Some examples are given in Fig. 3. Here "a" and "b" show examples of "cascade" showers. The three circular objects in the chamber are geiger counters seen end on. Pulses from the counters are fed into a network which expands the chamber and takes a picture only when a set of three pulses in coincidence (resolving time, 2×10^{-6} seconds) is obtained. The tracks show the paths of a shower of electrons passing through the chamber. Some are of low energy and are scattered by collisions with the gas molecules in the chamber, while others of higher energy show rectilinear tracks. Figure 3-c shows particles released in a nuclear explosion (called a star) that has taken place in the central geiger tube. The fainter track is that of a light high-energy particle (possibly a meson) which may have produced the explosion. The denser tracks are those of heavier and less energetic nuclear fragments. Figures 3-d and 3-e show tracks curved by a magnetic field perpendicular to the plane of the photograph. The track of a low energy meson is shown in "d." From the curvature its energy is computed as twenty-five million electron volts. The track in "e" is that of an alpha particle.

FIG. 2. SEMI-TRA'LER AND COSMIC RAY GROUP AT SITE OF TESTS
(L. to r.): C. E. Miller, physicist, D. Eng, electronic technician, Jay Todd, and D. S. Potter, graduate students, E. Wright, instrument maker

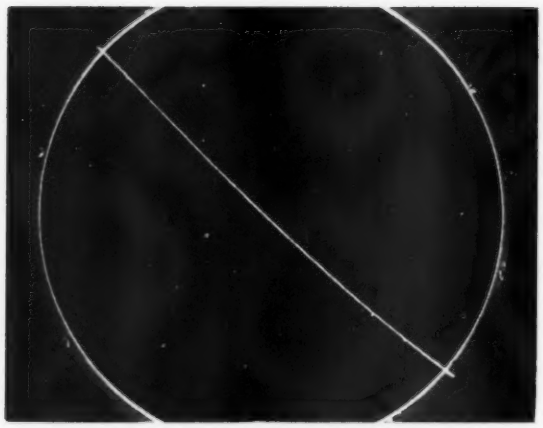


(a)



(d)

(b)



(e)

(c)

FIG. 3. TYPICAL COSMIC RAY TRACKS

(a) and (b) Medium-sized showers showing low-energy particles

(c) Tracks of particles produced in a nuclear explosion occurring in the wall of the central counter

(d) Track of light-weight particle of comparatively low energy

(e) Track of a high-energy alpha particle

(Contrast with lightly ionizing particle below in same picture.)

Thus far three expeditions to Colorado have been made. The average duration of such an expedition is about three months, during which time enough data are obtained (about 20,000 cloud-chamber pictures) to occupy us for several months in analysis. One extensive sea-level run has also been made, and another is just getting under way. Our prime objective has been to obtain certain details of the over-all picture, in particular, to determine the relative numbers of protons and mesons, and distribution of their energy. Such information is obtained by taking thousands of pictures of cosmic ray tracks, measuring the curvature produced by the magnetic field on each of the tracks, computing the momentum from this curvature, and then tabulating and plotting the results. Such a plot is shown in Fig. 4. The plot gives the number of particles of a given momentum (here, the intensity) in the number of particles per second per Bev per steradian per square centimeter as a function of the momentum.

Information of this nature is vital in gaining an insight into the nature of cosmic radiation and the effect of matter upon the extremely energetic particles and their reactions, which are involved. As yet, no laboratory device has been constructed which is capable of accelerating particles to such energies, and even the immense machines now under construction will fall far short of producing the particles now supplied from cosmic sources. Such research is tedious and time-consuming, but it appears to offer the only hope for studying nuclear reactions involving such large energies.

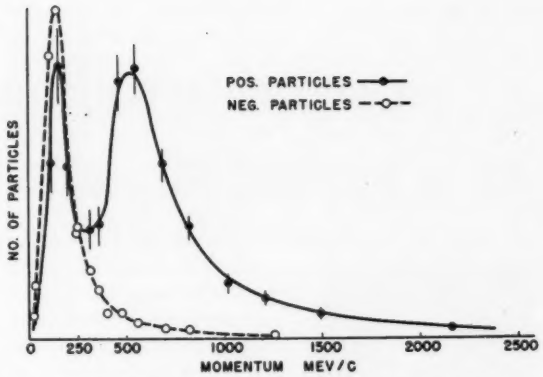


FIG. 4. MOMENTUM DISTRIBUTION OF PARTICLES OF RANGE 0.3 TO 5 CM PB

Although this laboratory is only one of many that are directing intensive efforts toward the study of cosmic ray phenomena, no one can predict how many years it will take to understand them completely.

MICROWAVE TUBE STUDIES SPONSORED BY ONR

Arrangements between the Department of Electrical Engineering and the Office of Naval Research for a project on microwave tube studies were completed recently. Dr. A. E. Harrison will supervise the research, which will utilize the enlarged facilities of the Microwave Laboratory.

The new project is an extension of the work started under the Engineering Experiment Station on the phase modulation of klystron tubes as a method of obtaining a microwave frequency standard. The scope of the studies has been expanded to include all phases of the modulation properties of microwave tubes, including cross-modulation characteristics. Experimental work will be correlated with an analytical study of the problem by Dr. L. J. Lewis.

Extension of the experimental work to include the properties of traveling-wave tubes as well as klystrons is under way. A traveling-wave tube has been obtained on loan from Stanford University and the project staff is now engaged in building the necessary power supplies and auxiliary radio-frequency equipment in the 3,000-megacycle frequency range.

Most of the equipment will be specially designed for the project. The power supply must be very well regulated and variable in output voltage over a wide range, but supplies very little current. The traveling-wave tube will also require a power supply for the magnetic focusing field and a regulated voltage supply for the heater power. These requirements introduce interesting problems in the design of the equipment.

The University of Washington is furnishing the measuring equipment required for the project. Construction of a microwave spectrum analyzer or panoramic receiver was begun last year in anticipation of the research contract; other items are on order, and delivery is expected by the time the auxiliary equipment is completed.

Results of the research will contribute to a knowledge and understanding of the operation of microwave tubes. Study of the modulation properties of such tubes, though essential in their application to microwave radio systems, has been somewhat neglected in the past in the scramble to determine the power-output capabilities, the frequency bandwidth, and the inherent level of noise generation of these systems.

OLIVINE: A FOUNDRY SAND AGGREGATE

GILBERT S. SCHALLER
Professor of Mechanical Engineering

W. A. SNYDER
Assistant Professor of Mechanical Engineering

G. S. Schaller

For hundreds of years, man has rammed, jolted, squeezed, or otherwise compacted mixtures of sand grains, clay, and water to form molds into which molten metal alloys could be poured to produce castings. This mixture or material, molding sand, when made into a mold must have sufficient strength to retain its shape. When the molten alloy is poured into the mold, the material must not erode under the forces of the heavy liquid. The mold must have the strength to withstand the pressure of the molten metal, yet must yield in order to avoid tearing the casting as it contracts while cooling. It must be sufficiently permeable to permit the escape of gases and vapors formed in the molding material at the time metal is poured and also gases that may be released from the molten alloy. At the metal-sand interface, the mold will be heated to a temperature approaching that of the molten metal. The expansion of the mold near the interface tends to tear it loose from its backing material. If the expansion of the mold material is too great, defective castings will result. The mold material must also resist temperature to the degree that it will not fuse to the surface of the casting.

Nature provided generous deposits of sand grains mixed with clay that, in their natural state, are suitable molding materials for many uses. These natural molding sands have been used for centuries and continue to be valuable molding materials in foundries everywhere. Natural sands, in many cases, do not have a sufficiently high permeability and fusion point for heavy iron and steel castings; in consequence, "synthetic" molding sands have been developed to meet these shortcomings.

Synthetic molding sand is compounded from specified sand grains, selected bonding clays, and organic materials to produce a material of required properties. Natural, clay-free, silica sand is generally used for the aggregate of synthetic molding sand in this country. The high fusion point, uniformity, and the low cost of mining and preparing silica sand make it a desirable molding material, especially in the areas near the deposits. Silica, however, has some salient disadvantages. One is found in its toxic effect on human lungs; workers breathing air carrying its dust are exposed to silicosis. Another shortcoming is its large nonuniform rate of expansion. A third difficulty, not inherent with silica but with the manner of its use, is its limitation in the selection of grain size and distribution to those available in easily worked natural deposits.

W. A. Snyder

An imposing amount of research has been conducted in investigating bonds and buffer agents for silica aggregate synthetic molding sands; yet relatively little study has been given to other aggregates. Crushed coke, burned and crushed fire clay, magnesite, aluminum oxide, and olivine have all been tried; but because of their high cost, or the cost of their preparation, the investigations have not been exhaustive.

The state of Washington has the largest deposits of high quality olivine rock in this country. Many foundries on the west coast use silica sand that is shipped from Ottawa, Illinois, or the beaches of Belgium. There appears, therefore, to be no economic barrier preventing the use of olivine in molding sand on the west coast. For this reason, and because it appears to have several advantages over silica, the Engineering Experiment Station of the University of Washington initiated a project to investigate the utility of Washington olivine as an aggregate for molding sand. The research work is being performed by A. L. Nelson, a research fellow in the Engineering Experiment Station, under the direction of the writers.

Olivine rock, magnesium-iron-ortho-silicate, does not contain free silica, and medical research indicates that it does not cause silicosis. Olivine has, in addition, a fusion point higher than silica and a low,

uniform rate of thermal expansion. Further, since it must be crushed and classified, selection of any spread of grain size is possible.

Olivine occurs in the area of the Twin Sisters Mountains in the Cascades, and on Cypress Island, as massive rock or boulders. At the present time, olivine from the Twin Sisters is being used in this investigation. The material, as supplied, was crushed to ¾ in. minus; it was roll-crushed at the University to minus 30 mesh, and air-classified to remove the fines. When the research requires a narrow spread of grain size, the material is water-classified.

The project began in the Foundry Sand Control Laboratory of the Mechanical Engineering Shops; various mixtures were compounded and tested. Mixtures that had promising mechanical properties were rammed into molds for the production of castings. These tests were of an exploratory nature as a starting point for the investigation. When satisfactory jobbing sand mixtures for iron and aluminum were found, all silica sand was removed from the student foundry, and the shop was thoroughly cleaned. This was essential since silica will flux olivine and lower its fusion point. The silica molding sand has been replaced in its entirety by synthetic olivine molding sand, and the foundry has since performed valuable service as a pilot plant for the research project, in addition to functioning as a student foundry laboratory. Here most of the processes used in commercial foundries can be duplicated, and laboratory developments can be tested under actual operating conditions. A variety of castings are produced by students in the foundry (Fig. 1). The first stage of intensive investigation has now been completed.

In this project, three olivine aggregates were tested, a coarse grain, a medium grain, and a fine

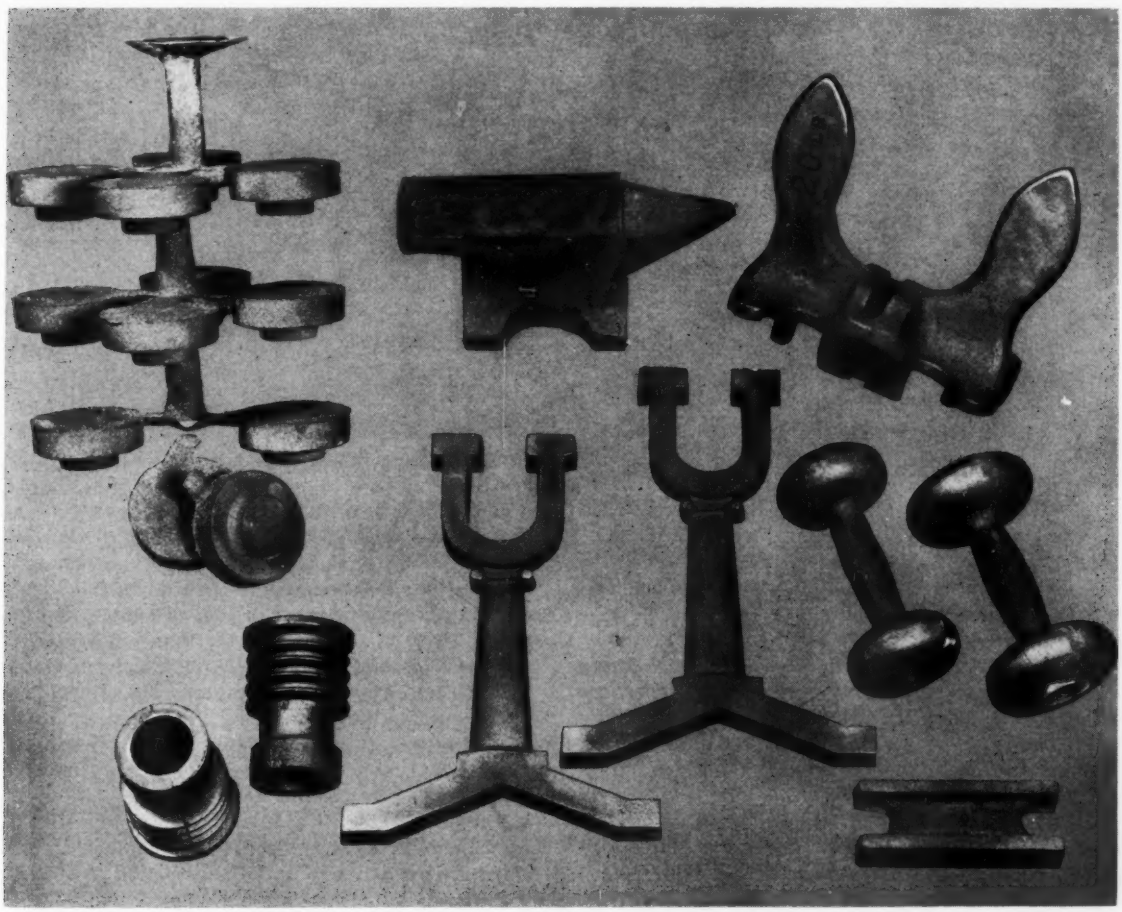
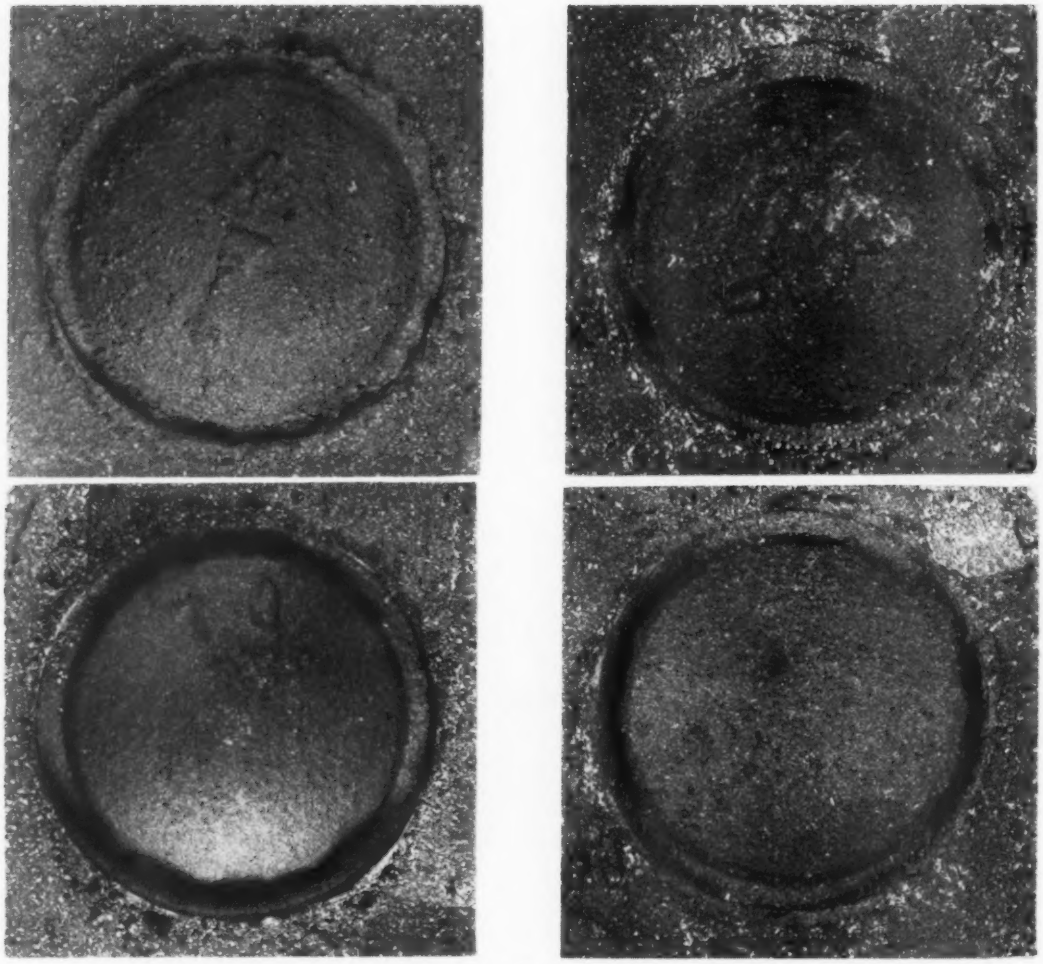


FIG. 1. TYPICAL CASTINGS PRODUCED FROM OLIVINE SAND MOLDS



F:G. 2. SURFACE SPECIMEN CASTINGS FROM VARIOUS GRAIN-SIZE COMBINATIONS OF OLIVINE AGGREGATE

grain. Western bentonite was the bonding material and several mixtures were prepared by varying the bond content and the moisture independently. Approximately 540 mechanical tests have been made on 66 mixtures. A surface specimen test casting was poured to develop the actual casting appearance produced by each mixture tested. As a result of the test data, it is now possible to specify the properties desired and estimate the grain size and bond required to give those properties. Obtainable surface smoothness can also be determined by examining the specimen castings, as shown in Fig. 2.

Further research will investigate the use of mold washes and atmosphere agents with olivine molding sand. Tests will also be made to determine whether or not casting defects due to expansion can be eliminated or reduced through the use of olivine.

It is intended to introduce olivine in gray iron as well as steel foundries in Seattle during the coming months and test it thoroughly under commercial operating conditions. As with any innovation, some difficulties are anticipated in this attempt to replace a foundry sand that had its beginning in antiquity, and the acceptance of olivine by the foundry industry will doubtless be marked by caution. However, pilot-plant results, buttressed with the research background of this investigation, give every indication of a successful undertaking, and when the industry understands the potentialities of olivine, it seems safe to predict that its acceptance will be widespread. In that event, the Engineering Experiment Station will have made a significant contribution to a basic industry and the state of Washington will become the source of supply for olivine foundry sand.

PRODUCTION OF OZONE WITH REFRIGERATED ANODES*

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ABSTRACT

By electrolysis of 40 weight per cent perchloric acid with refrigerated platinum metal anodes, electrolytic ozone of 58 weight per cent concentration has been prepared at energy efficiencies up to 24 grams ozone per kwhr. Maximum yields of ozone were attained with the internally cooled anode at −60° to −65° C, perchloric acid electrolyte at a bulk electrolyte temperature of −56° C, current density of 0.13 to 2.6 amp/dm², and a total pressure above the electrolyte of 10-100 mm Hg. Ozone current efficiency, weight per cent ozone, and grams of ozone per kwhr increase with decreasing anode and electrolyte temperatures, and with increasing current density.†

R. D. Hornbeck

Introduction

Yields of ozone above 20 weight per cent have previously been obtained by electrolysis of perchloric acid at low temperatures.[7] A recently completed study demonstrated that the temperatures of platinum metal anodes in perchloric acid are 3° to 20° C warmer than that of the electrolyte, under the optimum conditions for ozone production.[1] Since the ozone current efficiency increases very rapidly with decrease in temperature, and since ozone production occurs only at the anode surface, the control of anode temperature is of prime importance. The present work is a continuation and further exploration of that process with the aims of greater yields, higher energy efficiencies, and a better understanding of the process itself.

Briner, et. al.,[4,5] reported that yields of ozone up to 7.8 g/kwhr may be obtained by electrolysis of perchloric acid, and concluded that the acid gives somewhat lower yields than sulfuric acid. Since Briner erroneously believed it necessary to sweep out the ozone with a current of air, he succeeded in obtaining only very dilute concentrations, and since his highest yields were secured with a current of 0.05 ampere, his errors may have been large. In any event Briner and all other prior art workers[3,6] overlooked the singularly improved results obtainable with perchloric acid.

Experimental Apparatus and Procedure

Cell for Preparation of Hydrogen-Free Ozone. One of several cells having a refrigerated anode is shown in Fig. 1. The cell (henceforth, Cell No. 1) consists of two concentric glass tubes, fitted together with a standard 29/42 mm glass-tapered joint. The outer glass platinum-tube serves as the anode, while the cathode is a hollow cylinder of sheet platinum. The platinum glass seal consists of joining the platinum tube (2.5 cm OD, 5 cm long, 0.0025 cm wall thickness) to the glass by using a graded glass seal.

This cell was immersed in a methyl alcohol-dry ice bath so that the cross-arm was below the level of the refrigerant. A glass cloth diaphragm (Owens-Corning Fiberglass No. 118) was used to separate the cathode product, hydrogen, from the anode product, a mixture of ozone and oxygen.

Cell With Internally Cooled Platinum-Iridium Anode. A cell (Cell No. 2) having an internally-cooled 95 per cent platinum-5 per cent iridium tubular anode is shown in Fig. 2. The anode (25 cm

*Reprinted by permission from the *Journal of the Electrochemical Society*, Vol. 98, No. 4 (April, 1951).

†U.S. patent application pending.

G. L. Putnam

x 0.3 cm OD x 0.025 cm wall thickness) and the sheet platinum cathode were separated with Teflon spacers. No provision was made for the separation of the hydrogen and ozone-oxygen mixture. Four ports were made up in the top, one for the electrolyte thermocouple, one for the cathode connection, and two for the tubular anode. Dow-Corning silicone stop-cock grease was used as the lubricant.

Methyl alcohol, cooled by pumping through a copper coil and storage cylinder immersed in a methyl alcohol-dry ice bath (ca. –80° C), was used as the internal refrigerant for the anode (Fig. 3). To further assist in the refrigeration, the entire cell was immersed in a dry ice-40 weight per cent perchloric acid bath.

The absorbers, shown in Fig. 3, were constructed from standard 34/45 mm glass joints. Two were used in series to insure complete absorption of the ozone in the potassium iodide absorbent.

All seals of the absorber and vacuum apparatus were either standard taper glass seals or stopcocks. The other seals used were ¼ in. (0.6 cm) Tygon tubing, an ozone-resistant elastomer. Vacuum was maintained by an oil seal vacuum pump. The apparatus was designed so that vacuum could be maintained on the cell while the ozone-absorbing tubes were being drained and refilled.

The cell was filled with 40 weight per cent perchloric acid electrolyte. Dry ice and methyl alcohol were added to the reservoir and the circulating pump turned on. To attain steady-state conditions, the cell was permitted to operate for at least one hour before any samples were taken. Each absorber contained a mixture of 40 ml of *2M* KI and 10 ml of distilled water. The duration of each run was five minutes, timed by a stop watch. The temperature was controlled by adding dry ice to the bath, the flow rate of the refrigerant being controlled with a valve and by-pass arrangement. Temperatures were determined with standard copper-constan thermocouples and a Leeds & Northrup No. 8662 precision potentiometer. After absorption of ozone, the absorbent solution was washed into a 500 ml erlenmeyer flask and the liberated tree iodine was titrated with a standard sodium thiosulfate solution.

E. D. Boelter

Determination of Ozone. Boelter, Lash, and Putnam[2] have recently standarized the potassium iodide method by an absolute method and have reported the conditions necessary for determination of ozone in concentrated mixtures of electrolytic ozone. It has been shown that in this case it is necessary to add strong acid before titration.

Ozone was determined by absorbing in 40 ml of *2M* potassium iodide solution and 10 ml distilled water, followed by acidification with 10 ml of *6N* H_2SO_4, and titrating the liberated free iodine with standard sodium thiosulfate solution.[2] Current efficiencies were calculated on the basis that both oxygen and ozone have an equivalent weight of 8.

Discussion of Results

With Cell No. 1, hydrogen-free ozone-oxygen mixtures could easily and uniformly be obtained having more than 20 weight per cent of ozone. The yield increased from essentially no ozone at room temperature to more than 20 weight per cent at an electrolyte temperature of about –50° C, the cell having a 40 weight per cent perchloric acid electrolyte and being immersed in a methyl alcohol-dry ice bath. Anode current densities of 10 to 40 amp/dm^2 gave good results. When 100 ml of the ozone-oxygen anode product were absorbed in alkaline pyrogallol, no trace of undissolved hydrogen remained. When attempts were made to replace the platinum cathode with lead, corrosion of the lead caused difficulties. It is possible, however, that with a continuously operating cell, the platinum cathode could be replaced with lead.

Effect of the Anode Temperature. Cell No. 2 was used primarily to study the effects of anode temperature, current density, and absolute pressure above the electrolyte on the ozone concentration and yields.

In all cases the ozone current efficiency and energy yields increased with decreasing anode temperature. Figure 4 shows the effect of the anode temperature. That the plots are linear is due to the fact that temperature range was small.[7] The average anode temperature was determined by two copper-constantan thermocouples in contact with the platinum anode at positions entering and leaving the cell.

The electrolyte was maintained six to ten degrees warmer than the average anode temperature. The lower limit of the temperature is the freezing point of the electrolyte (–56° C).

Effect of the Current Density. In previous work with uncooled anodes and constant bulk electrolyte temperature, current density did not appear to be an important variable.[7] When the anodes are not cooled

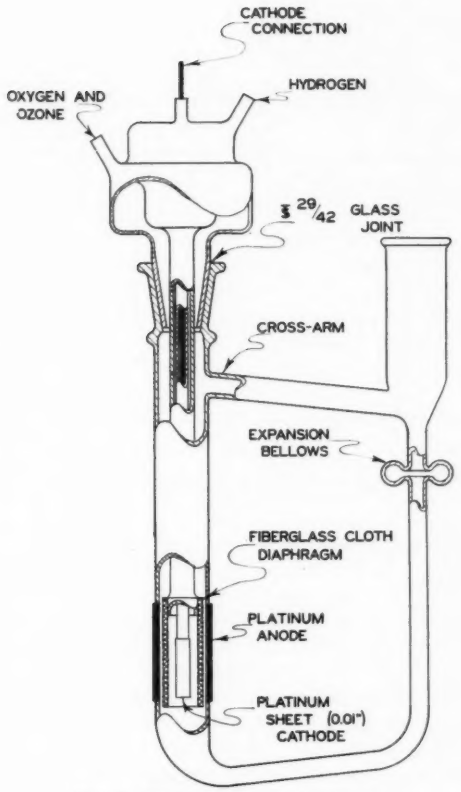


FIG. 1. CELL FOR PREPARATION OF HYDROGEN-FREE OZONE

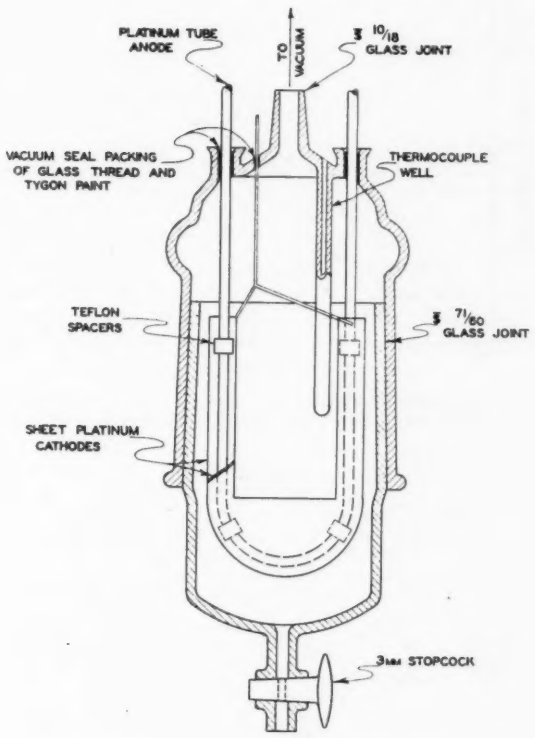


FIG. 2. CELL WITH INTERNALLY COOLED PLATINUM-IRIDIUM ANODE

(The cathode consisted of two sheets of platinum, one on each side of the tubular anode.)

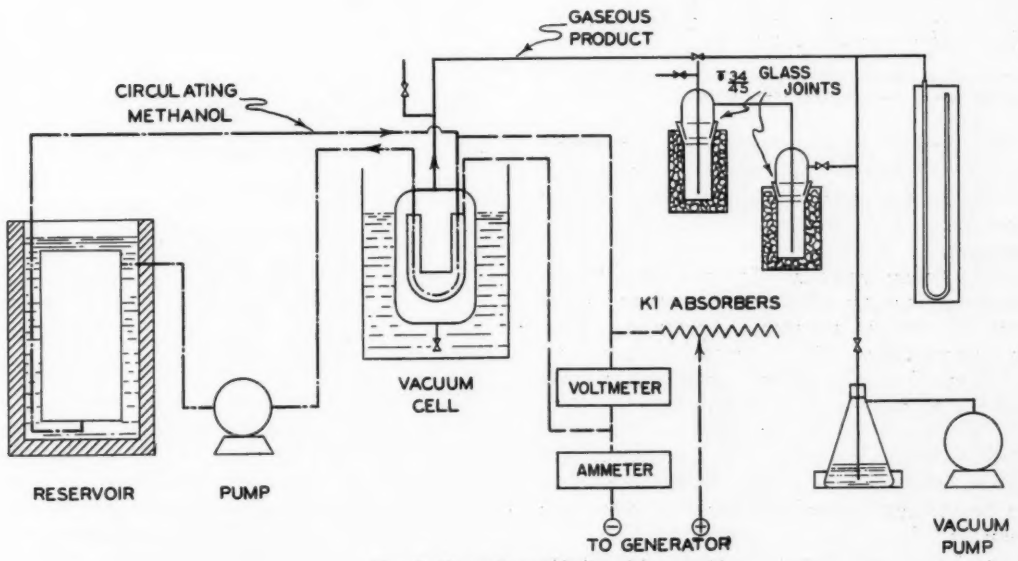


FIG. 3. FLOW SHEET OF SYSTEM

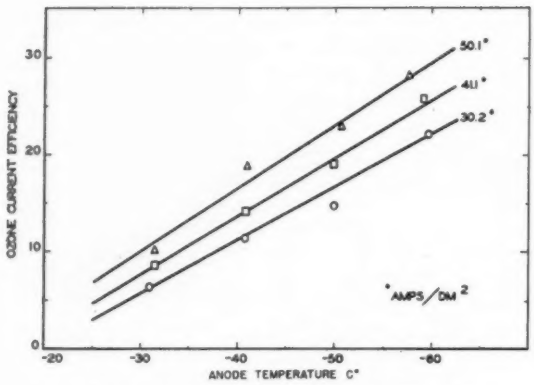


FIG. 4. OZONE CURRENT EFFICIENCY AS A FUNCTION OF ANODE TEMPERATURE AT ATMOSPHERIC PRESSURE

TABLE I

OZONE CURRENT EFFICIENCY AS A FUNCTION OF CURRENT DENSITY AND ANODE TEMPERATURE AT ATMOSPHERIC PRESSURE
(Cell No. 2)

Avg anode temp °C	Anode current density (amp/dm²)	Volts	Ozone current efficiency %	Weight % ozone	Grams of ozone per kwhr*
−31	29.5	4.60	6.41	5.70	4.12
−31.5	40.9	5.05	8.59	7.64	5.06
−31.5	50.9	7.02	10.16	9.04	6.00
−40.9	29.8	5.20	11.59	10.30	6.64
−40.9	41.2	5.21	14.20	12.63	7.75
−41	49.8	6.10	18.60	16.54	9.24
−50	30.8	5.40	14.75	13.12	8.12
−50	41.3	5.82	18.95	16.85	9.70
−50.7	49.9	6.30	22.90	20.40	10.85
−59.8	31.0	7.70	22.30	19.82	8.77
−59.1	41.1	7.78	27.75	22.90	9.87
−59.8	50.1	7.40	28.20	25.10	11.33

*Does not include power necessary for refrigeration.

by direct contact with a refrigerant, the anode-electrolyte temperature differential increases with increasing current density,[1] and this would tend to decrease the yield at constant *anode* (not electrolyte) temperature.

Figure 5 clearly shows the effect of current density on the ozone current efficiency at constant anode temperature, and at atmospheric pressure. At an anode temperature of −50° C, increase in the current density from 30 to 50 amp/dm² increased the ozone current efficiency from 16 to 23 per cent.

The logarithm of the current efficiency is a linear function of the anode temperature, the curves being of approximately the same slope as the curves obtained by plotting current efficiency vs. electrolyte temperature.[7]

Energy Yields and Ozone Concentration. Energy

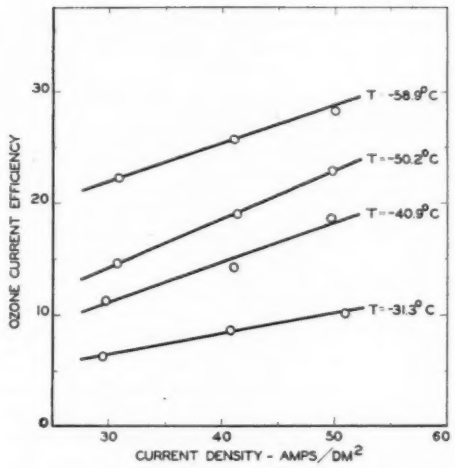


FIG. 5. OZONE CURRENT EFFICIENCY VS. CURRENT DENSITY

yields are a function of two opposing factors. With decrease in the electrolyte and the anode temperatures, the energy yield and ozone current efficiency increase. In addition the resistance of the cell increases with decreasing temperature due to the increased viscosity of the electrolyte.

Conditions for maximum ozone concentration (58 weight per cent) are as follows: 40 weight perchloric acid electrolyte, average anode temperature −62° to −65° C; bulk electrolyte temperature should approach the freezing point (−56° C); anode current density, 0.13 to 2.6 amp/dm;² voltage 8 to 13; and a total absolute pressure above the electrolyte from 10 to 100 mm Hg. Because of entrainment of the electrolyte at lower pressures, it was necessary to limit the average anode current density. It is possible that much of the anode was covered with a film of frozen electrolyte, insulating parts of the anode and locally increasing the current density. Lowering the pressure causes some increase in yield.[7]

For maximum energy yields (24 grams ozone per kwhr) the conditions are very similar to those for maximum ozone concentration with the exception of the bulk electrolyte temperature. In this case it should be a few degrees above its freezing point, in order to lower the cell resistance, and the voltage required is 8 volts. Recommended electrolyte temperature is −50° to −53° C for the maximum energy yields.

Conclusions

The following conclusions are drawn from this study:

1. By electrolysis of 40 weight per cent perchloric acid at low temperatures, low pressures, and with

(Continued on page 32)

Traffic Engineers Confer on Campus

The Fourth Annual Northwest Traffic Engineering Conference was held at More Hall, May 17 and 18, sponsored by the western section of the ITE, the Washington State Highway Department, and the University Department of Civil Engineering. Attendance included registrants from Idaho, Oregon, Washington, and California.

The Thursday morning session was opened by Chairman W. A. Bugge, Washington State Director of Highways, who introduced Dean Harold E. Wessman of the College of Engineering. Dean Wessman's address of welcome was followed by papers by Bruce Crandall, Traffic Engineer of the Oregon State Highway Department ("Traffic Engineering Activities"), J. R. Sargent, Division Planning Engineer, U. S. Bureau of Public Roads ("Transportation Programming"), and Norm Kennedy, Associate Engineer, Institute of Transportation and Traffic Engineering, University of California ("Traffic and Transportation").

The afternoon session, with M. E. Ray, City Supervisor of Pullman, Washington, presiding, was devoted to a discussion of parking problems in papers presented by Chester Biesen, Executive Secretary of the Washington Association of Cities ("The Cities Look at Off-Street Parking"), J. Diamond of the Diamond Parking Stations, Inc. ("Parking in Relation to Business"), R. I. Perkins, Superintendent of Schedules, Portland Traction Co. ("Parking and Mass Transportation"), H. Aumack, Traffic Engineer of Spokane ("Parking and Driver Convenience"), and M. Dederer, Traffic Committee Chairman, Seattle C. of C. ("What's Preventing Cities from Going into the Parking Business?").

Speakers of the Friday morning sessions under Chairman W. W. Stiffler, Assistant State Highway Engineer, Oregon Highway Department, discussed route design and evaluation. R. W. Finke, Seattle City Engineer, spoke on "Urban Freeways," R. E. Dunn, Assistant Traffic Engineer, Washington State Highway Department, on "Urban Highway Evaluation," E. F. Emmick, Road Design Engineer of the W.S.H.D., on "State Highway Design," and E. L. Mathes, Traffic Engineer, Idaho Bureau of Highways, on "Rural Intersection Design."

J. S. Roberts, Tacoma City Commissioner of Public Works, presided over the concluding session of the Conference, which dealt with public relations and planning. Papers presented were "Some Objectives of a City Master Plan" by J. H. Bell, Portland landscape architect; "Transportation Planning at the County Level," by W. A. Stancer, Pierce County Engineer; "Transportation Public Relations and the Press," by William Schulze of the *Seattle Post-Intelligencer*; "Transportation Public Relations and the Radio," by Burt McMurtie of Tacoma Station KMO; and "Transportation in Municipal affairs," by Paul Seibert of the Seattle Municipal League.

W. H. Carsten, Assistant Planning Engineer, W.S.H.D., was general chairman of the Conference.

U. of W. and National Bureau of Standards Contract for VHF Field Studies

The Central Radio Propagation Laboratory of the National Bureau of Standards has contracted with the University for a year's series of very high frequency field studies.

The Tropospheric Propagation Research Section of the Laboratory is interested in the recording of field strength measurements at about 100 megacycles from standard broadcasting stations in the Portland, Oregon, area.

Propagation at this frequency and over this distance is a function of the troposphere, and the data collected will be used in testing fundamental theories of radio wave propagation in predicting optimum usable frequencies for long-distance transmission as well as ionospheric disturbances.

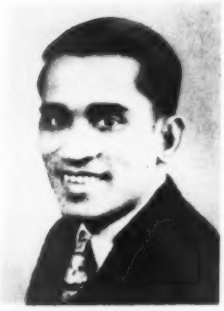
The contract, No. CST-481, provides about $4,000 for the cost of tests up to July 1, 1952.

H. M. Swarm, instructor in electrical engineering, will devote part of his time to supervising the project. Glenn Keitel, a senior student in E.E. is assisting in setting up the equipment. Data are being recorded on Esterline-Angus recording tape. Each hour, medians of field strength measurements are scaled from the tape, and tabulations are sent to the Bureau of Standards in monthly reports.

STUDIES OF THIN FILMS BY ELECTRON DIFFRACTION*

N. R. MUKHERJEE
Associate in Chemical Engineering

OLIVER H. ROW
Electron Microscopist
Engineering Experiment Station



N. R. Mukherjee

In attempts to prepare samples for electron diffraction powder patterns, studies of the difficulties involved led to a method for making samples under controlled conditions. This method provided an opportunity to study the optimum conditions for getting good diffraction patterns.

It is known that the width of the diffracted ring is a function of particle size.[1] We find that samples prepared in the following way show diffraction patterns with narrow (*i.e.*, sharp) rings, a greater number of rings than usual, and a better contrast between the rings and the background at a critical thickness.

Most methods of preparation of diffraction samples use a substrate as supporting medium, e.g., collodion, formvar, etc. Other methods use cellulose compounds or some crystals, which may be dissolved away leaving the sample in pure form. In the present technic a water-soluble plastic film, such as Elvanol† is used as a substrate upon which a film of material is deposited by evaporation as described below. A 15 per cent aqueous solution of Elvanol is spread evenly on a flat glass plate and allowed to dry slowly. On drying, the film is peeled off, cut into proper dimensions and stuck to a flat plate (2-cm by 1-cm aluminum plate) using moisture as a cement. Nine such supported elvanol films are placed tangentially on the arcs of nine concentric circles, the center of which is at the point source of evaporation. A known weight of metal, which is put in a conical filament of tungsten or other suitable material,[2] is located at the horizontal plane passing through the centers of all the nine films mounted vertically. The metal is evaporated completely under high vacuum ($>10^{-4}$ mm Hg). Then each metal film with the substrate is peeled off and laid on the surface of an undisturbed water bath for dissolution of the substrate. The diffraction samples are made from the substrateless floating film by placing an electron microscopic screen disk on a flat top brass cylinder and bringing it from under the floating film, thereby catching a piece of film on the screen. After slow drying the screen with the sample is placed in the electron diffraction camera.

O. H. Row

For illustration of a typical sample the diffraction pattern of aluminum as obtained by evaporation is shown in Figs. 1 to 3. The results are reproducible. Approximate thicknesses as calculated by inverse square law are 1300 Å, 580 Å, and 240 Å respectively. The diffraction pattern in Fig. 2 is definitely superior to those in Figs. 1 and 3, with respect to sharpness of the rings, number of rings, and contrast of the rings against the background. Absence of substrate eliminates inelastic scattering caused by it and produces diffraction pictures without undesirable haziness. Most of the published diffraction pictures of aluminum show about eight rings,[3] whereas 24 rings are found in Fig. 2. (In the negative there are 27 rings.) From the sharpness of the rings it is believed that the particles obtained by evaporation are of appropriate size.

Further studies will be published later.

*Reprinted by permission of the *Journal of Applied Physics*, May, 1951.

†Elvanol (grade 51-05) was supplied by courtesy of DuPont de Nemours & Co.

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2. CALDWELL, W. C., *J. App. Phys.* 12, 779 (1941).
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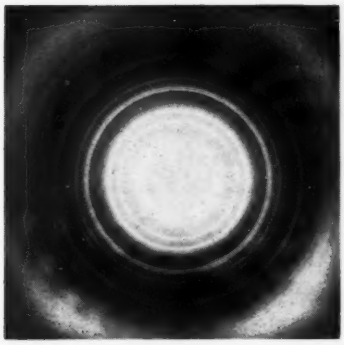


Fig. 1. Diffraction Rings of Al—1300 A°

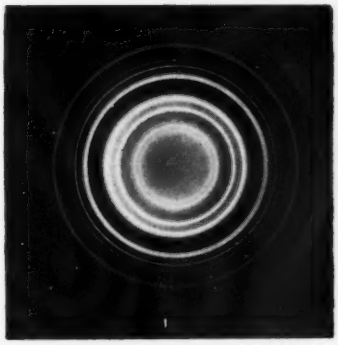
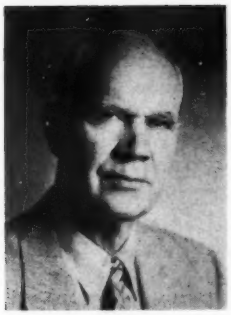


Fig. 2. Diffraction Rings of Al—580 A°

Fig. 3. Diffraction Rings of Al—240 A°

Professor Tyler to Advise Israeli Government



R. G. Tyler

R. G. Tyler, Professor of Sanitary Engineering, who has been appointed a member of the public health unit of a United Nations medical teaching mission to Israeli, will leave for Europe the middle of July. He will first visit water-ozonation plants in France and England, in connection with an ozonation research project of the Engineering Experiment Station now in progress. Such cities as Paris, Lyons, and Nice have long made use of ozone in water treatment for pollution.

August 28-29, the 14-man mission, which includes scientists from five countries in the fields of anatomy, biochemistry, internal medecine, neurosurgery, pediatrics, and psychiatry, will meet in Geneva for briefing at the headquarters of the World Health Organization, thence proceeding to Israel where they will consult with officials and educational leaders on problems of medicine, public health, and sanitation.

The report of the first session of the World Health Organization's Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel, which met in Geneva last December, set forth standards of education in medecine, public health, nursing, sanitary engineering, psychiatric and medical social work, and industrial health. The Committee also considered such questions as fellowships, including those in foreign institutions, exchange of scientific information, technical assistance for economic development, and cooperation with other international organizations.

The mission of which Professor Tyler will be a member, is among the first to be appointed in connection with the Committee's proposed plan of visiting consultants, as outlined in a tentative long-term program for the next five years.

The mission's work will continue throughout September and October. Professor Tyler expects to return to the University of Washington at the beginning of the winter quarter, by way of Singapore, Tokyo, and Honolulu.

COAL REPORT AROUSES INTEREST

Experiment Station Report No. 6, *The Chemical Utilization of the Subbituminous Coals of Washington*, by Dr. Lorentz A. Conradi, published in September, 1950, although directed especially toward regional problems, has been quoted extensively and has received recognition from many sources. Following distribution of about 2,000 copies to the regular mailing list for such a publication, the Washington Committee of State Industrial Development requested 100 copies for distribution among its members and other interested individuals and firms.

Reviews in *Chemical Engineering* and *Coal Age* brought a flood of inquiries from Florida to Oregon and Alaska to Hawaii, as well as a number of letters from South America.

The November (1950) *Supplement* to the *Monthly Review* issued by the Federal Reserve Bank of San Francisco made extensive use of the report as a reference in its monograph, "Western Power and Fuel Outlook," by Wilfred Eldred.

HIGH-FREQUENCY LOSSES IN ELECTRIC CONDUIT

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Associate Professor of Electrical Engineering

JAMES W. CASPERS
Research Fellow, Engineering Experiment Station

W. R. Hill

SUMMARY

The electric codes give current ratings for conductors in metallic conduit based on temperature rise with 60-cycle alternating current flowing. At higher frequencies, such as those used in induction heating, increased copper losses and power loss in iron conduit require a decrease in the safe current-carrying capacity of the conductors. This paper reports the results of an investigation of these losses and gives curves showing the effect of frequency upon safe current rating for a range of conductor sizes. The curves show that it is not practicable to transmit large amounts of high-frequency power with standard conductor-conduit construction.

J. W. Caspers

Introduction

The National Electric Code and local electric codes patterned after this code give extensive tables showing the allowable safe current ratings of copper conductors in metallic conduit. These ratings are based on the allowable temperature rise that can be continuously withstood by the various types of insulation and are the result of extensive studies of the temperature rises produced by confined current-carrying conductors.

At a frequency of 60 cps almost all the power loss takes place in the copper conductors and can be computed from the simple I^2R formula, where I is the current and R represents the conductor resistance. At frequencies above one kilocycle per second, however, the power loss increases for two reasons. First, the effective conductor resistance increases because of skin effect or redistribution of the current flow toward the conductor surface. Second, the alternating magnetic field produces eddy-current and hysteresis losses in the iron conduit which produce heat and raise the conductor temperature. For large conductors in big conduit the increased power loss is serious and greatly reduces the allowable current-carrying capacity of the conductors.

At present the electric codes make no provision for reducing the ratings of conductors in conduit carrying high frequencies, but with the increased interest in transmitting power at these frequencies, particularly for induction heating, it is desirable to have information regarding allowable current ratings. Consequently, the evaluation of conductor losses at advanced frequencies was attempted as a portion of High-Frequency Heating Project No. 12 of the Engineering Experiment Station.

Results

The curves of Figs. 1 and 2 summarize the experimental results obtained for insulated copper conductors in iron conduit. Figure 1 shows the reduction of current-carrying capacity required at a high frequency to keep the total power loss equal to that at 60 cycles for which ratings are already established by code. For example, at 5 kilocycles a pair of No. 6 wires in 1-in. conduit can carry only 64 per cent of normal rated current. The serious derating required for the large conductors clearly indicates the undesirability of using standard construction for transmitting large currents at frequencies much above 1 kilocycle.

Figure 2 shows a cross plot of the information of Fig. 1 and indicates the maximum allowable frequency that different wire sizes can carry without a significant decrease in current-carrying capacity. The reduction taken as significant is purely arbitrary, but in view of the experimentally observed variations due to conductor position within the conduit, the obvious rounding off employed in the code ratings, and the uncertainties regarding ambient temperatures, etc., a rating reduction of 0.8 was considered reasonable as the limiting value.

The ratings reported in Figs. 1 and 2 are based entirely upon power loss measurements for somewhat idealized conditions; these results have been rounded off with interpolations based on theoretical considerations to produce a reasonably smooth set of curves. Since the different wire sizes involve

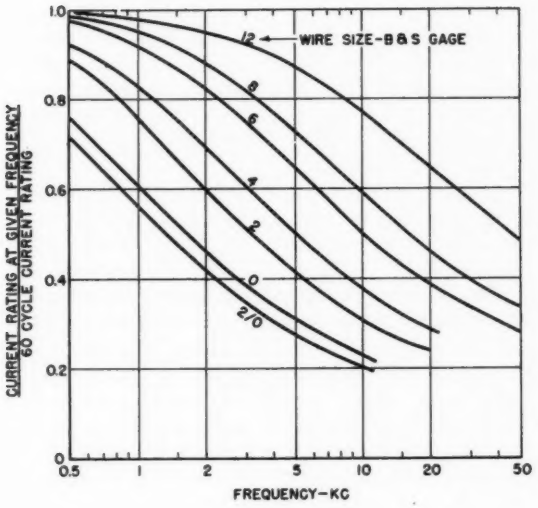

FIG. 1. REDUCED CURRENT RATING AT HIGH FREQUENCIES FOR COPPER CONDUCTORS IN IRON CONDUIT

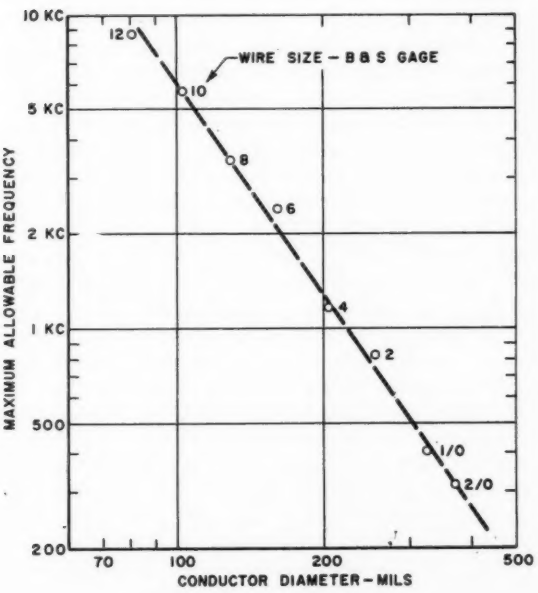

FIG. 2. MAXIMUM ALLOWABLE FREQUENCY FOR COPPER CONDUCTORS IN CONDUIT WITHOUT SERIOUS REDUCTION OF CURRENT-CARRYING CAPACITY

(Based on curves of Fig. 1 for a rating reduction factor of 0.8.)

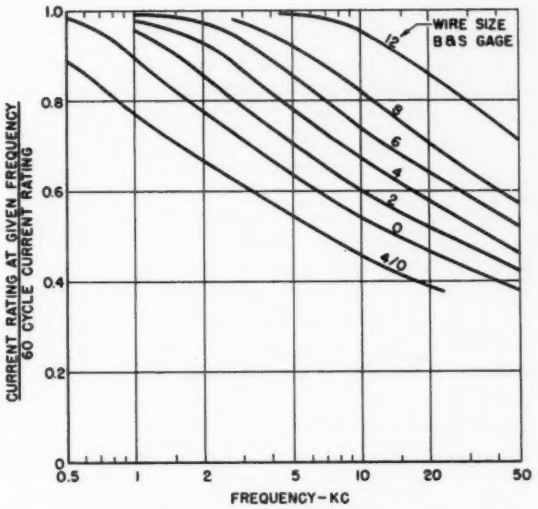

FIG. 3. REDUCED CURRENT RATING AT HIGH FREQUENCIES FOR COPPER CONDUCTORS IN NONMETALLIC ENCLOSURE

different sizes of conduit the curves tend to be slightly discontinuous as shown by the points of Fig. 2. Ratings based on power loss rather than upon temperature measurements tend to be uniformly pessimistic. At high frequencies the majority of the power loss takes place in the conduit instead of in the conductor, which certainly results in a lower insulation temperature than if the loss had taken place in the conductor with all the heat passing through the insulation to reach the outside air.

For comparison purposes, to show the advantage of employing a nonmetallic conduit, the curves of Fig. 3 display the effect of high-frequency operation on the current rating of copper conductors in air or nonmetallic enclosure, transite, for example. These curves are computed from standard tables of skin effect and are similar to those of Fig. 1 except that the drop in rating occurs at a considerably higher frequency. The curves are calculated for equal power loss at the rated frequency as compared to 60 cycles; since all the loss takes place in the conductor they should represent an equivalent temperature rise.

Experimental Justification

Two methods of establishing the rating information of Fig. 1 suggest themselves. One is to actually pass large currents through the conductors in conduit, determine the temperature rise, and find the current reduction necessary to produce the same temperature rise as that produced by rated current established by code at a frequency of 60 cps. This would require a variable-frequency current source

of over 100-ampere capacity covering the range from 500 cycles to 50 kilocycles.

Another approach is to accurately measure the equivalent resistance of conductors in conduit over a range of frequencies and base the rating upon equal power loss. This power loss produces the heating and hence is related to the temperature rise. This method does not require a high-power source of energy but it does require an accurate bridge circuit capable of measuring the resistive components of the very low impedances presented by short lengths of conductor conduit. The experiments reported here employed this second method.

The design, construction, and calibration of an impedance bridge for this purpose is reported in a thesis by the junior author of this paper, entitled "Bridge Measurement of Small Resistive Components of Inductors at Audio and Low Radio Frequencies." Since the impedance range centered at about 0.1 ohm, the design paid special attention to the small stray self and mutual inductances normally negligible in a bridge designed for higher impedance. The construction employed concentric construction of conductors and bridge elements, water cooling of the standard of resistance which had to be small to keep the inductance down, and the introduction of carefully adjusted mutual inductance to cancel unavoidable residual inductance. The final bridge provided a better accuracy than was actually needed to get significant results.

Measurements were made of various combinations of conductors in conduit at frequencies up to 50 kilocycles. As might be expected the results varied greatly, depending upon the coupling between the conductors and the conduit. With the conductors closely spaced to produce a minimum of magnetic field, the losses in the conduit were less than for conductors spaced as widely as possible. Since one purpose of these tests was to separate, if possible, the conduit losses from the conductor losses, the majority of the tests were made with carefully spaced conductor pairs just filling the conduit diameter. While this produced the maximum possible loss, and would thus give an over-safe rating, it reduced the number of variables and permitted a more accurate determination of the trend as a function of frequency and conduit size. The final rating curves of Fig. 1 were computed using a reduced conduit loss to correspond approximately to the measurements made on loose conductors in a conduit.

The experiments showed that it was roughly possible to separate the conduit losses from the conductor losses. This was done by taking careful measurements with the conductors in the conduit and again without the conduit. These measurements disclosed that the apparent resistance increase was essentially a function of the conduit size and conductor spacing and only secondarily a function of conductor size. This made it possible to obtain curves of that portion of the equivalent resistance due to the conduit as a function of conduit size. The data obtained this way produced smooth curves for any one conduit and wire size, but the correlation between runs with different conduit sizes was not particularly good, probably because of inability to hold the relative coupling between conductors and conduit to a constant value.

The losses in the conduit consist of eddy-current losses caused by the voltages induced in the walls by the alternating magnetic field of the conductors, and hysteresis losses produced directly by the flux variations. For simple cases the variations of these losses with frequency and flux density is well known, but at the higher frequencies in solid iron the redistribution of the magnetic field complicates the problem and no clear-cut separation between the two types of losses could be made. One single test with a copper conduit showed a much lower loss than did the iron, which suggested that hysteresis losses were an important factor.

An additional investigation included the effect of the current magnitude upon the effective resistance measured by the bridge. Since the iron losses do not necessarily increase directly as the square of the conductor current, the resistance might vary with current amplitude. Tests at a fixed frequency showed that this did take place and that the resistance increased perhaps 20 per cent from very low currents up to a value of about 20 amperes. This was so much smaller than the changes produced by variations in coupling between conductors and conduit that it was not an important factor in affecting the ratings shown.

All of the ratings of Fig. 1 are pessimistic and will probably result in lower than rated temperature rise. At the higher frequencies, particularly with the large conductor and conduit sizes, the majority of the power loss takes place in the conduit rather than in the conductor. At low frequencies for which code ratings are given, all of the loss takes place in the conductors, and this heat flowing through the thermal resistance of insulation, air space, and conduit produces an allowable temperature rise in the insulation. At a higher frequency most of the loss takes place in the conduit itself and the heat has only to flow through the conduit walls and outer air film to reach the outside. Consequently the temperature rise will be less than before and the insulation will be cooler. Since the true rating depends essentially upon the temperature rise of the insulation, ratings based on power loss alone provide an over-cautious performance standard.

(Continued on page 32)

SLIP OF STRUCTURAL STEEL DOUBLE-LAP JOINTS ASSEMBLED WITH HIGH-STRENGTH BOLTS

PART II. EFFECT OF SURFACE CONDITION OF FAYING AREA UPON SLIP

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SYNOPSIS

A previous report* described twenty-three tests of plain-carbon structural steel double-lap joints assembled with high-strength bolts. All these joints had mill-scale faying areas. This paper reports the effect of other surface conditions of the faying areas upon the slip of the joint, such as mill-scale finish with drilled holes, mill-scale finish with subpunched and reamed holes, red-lead paint, varnish, and sandblasted finish. Eighteen joints were tested in this series.

Tests and Test Methods

The specimens were fabricated and tested in the manner described in Part I of this paper. Only the treatment of the faying areas was different.

Table I lists the test program and Fig. 1 gives the details of the specimens.

Four specimens had mill-scale faying surfaces and drilled holes. The bolt holes in the lap plates of three specimens were subpunched 15/16 inch in diameter. The bolt holes in the center plates were drilled 15/16 inch since specifications ordinarily prohibit punching of one-inch plate. The specimens were assembled and the holes were reamed to 1-3/64 inches in diameter. This procedure assured concentricity of the holes. The punching slightly dished the lap plates in the vicinity of the holes. The specimens were assembled so that the dished side of one lap plate was bearing on the center plate and the dished side of the other lap plate was away from the center plate.

The faying surfaces were wire-brushed to remove loose mill scale. Grease or other foreign material was removed with carbon tetrachloride and clean rags. Paint or varnish was then applied to some of the specimens. The varnish, a fast-drying type, was allowed to dry for about a week. The paint used was red lead, and was allowed to dry in a warm room for thirty days. The faying areas of three specimens were sandblasted. The specimens were assembled after the faying surfaces had been treated and the plates aligned so that the bolt holes were as concentric as possible.

* See Part I: "Effect of Bolt Tension and Faying Area upon Slip," *The Trend in Engineering*, April, 1951.

TABLE I

PROGRAM OF TESTS

Spec. No.	Type of Spec.	No. of Bolts	Surface Condition	Faying Area per Bolt sq. in.	Bolt Tension Kips
Effect of Surface Condition upon Slip					
13-15B 48-50 51-53 54-56 74-76	C	4	Mill scale Red lead Varnish Sandblasted Subpunched and reamed holes	32	45
Effect of Sustained Load upon Slip					
40-41	B	2	Mill scale	32	24

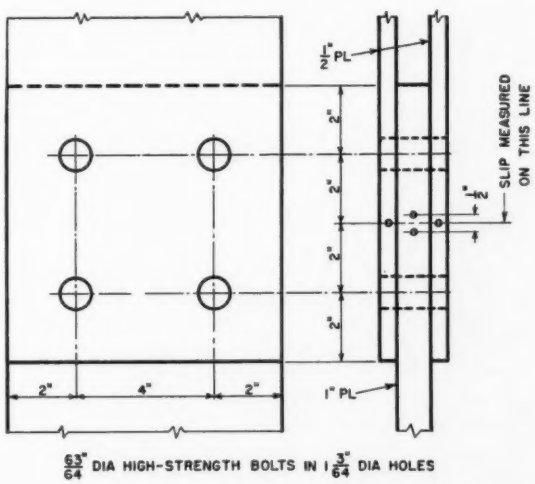


FIG. 1. TYPE OF DOUBLE-LAP BOLTED JOINTS USED IN TESTS

TABLE II

SUMMARY OF DATA

Specimen No. (1)	Type Specimen (2)	No. of Bolts (3)	Faying Area per Bolt sq in. (4)	Surface Condition (5)	Avg Bolt Tension kips (6)	Nominal Bolt Shear		P/A at 1st Slip ksi (9)	Coefficient of Friction at 1st Slip (%) (10)
						First Slip ksi (7)	Full Bearing ksi (8)		
13					45.1	17.2	26	17.8	29
14	C	4	32	Mill Scale	45.3	24.7	28	25.5	42
15A					46.0	21.6	..	22.3	36
15B					44.8	22.0	31	22.7	37
									(36)
48					44.6	....	21	....	..
49	C	4	32	Red Lead	44.9	....	..	....	..
50					45.0	....	..	....	..
51					44.4	....	..	....	..
52	C	4	32	Varnish	45.5	....	..	....	..
53					44.8	....	..	....	..
54					45.6	26.2	25	27.0	44
55	C	4	32	Sandblasted	44.7	22.5	26	23.2	38
56					44.7	34.6	33	35.6	59
									(47)
74				Subpunched	44.9	20.6	26	21.2	35
75	C	4	32	and Reamed	44.6	19.3	30	19.9	33
76				Holes	45.4	20.1	28	20.7	34
									(34)
40	B	2	32	Mill Scale	24.5	12.4	20	6.4	38
41					23.6	10.9	18	5.6	35
									(37)

DESCRIPTION OF SURFACE CONDITIONS

Designation	*Description*
Mill Scale	Mill scale surface, wire-brushed, and cleaned with carbon tetrachloride.
Red Lead	Wire-brushed and cleaned mill scale covered with one coat of red-lead paint. Paint aged 30 days before assembly.
Varnish	Wire-brushed and cleaned mill scale covered with one coat of fast-drying varnish. Varnish aged a week before assembly.
Sandblasted	Mill scale completely removed. Surfaces cleaned with carbon tetrachloride.
Subpunched and Reamed Holes	Holes in lap plates subpunched $^{15}/_{16}$ inch in diameter and reamed. Holes in center plate drilled $^{15}/_{16}$ inch in diameter and reamed. Lap plates slightly dished around holes by punching.

Data of Tests

1. ***Effect of Surface Conditions upon Slip of Bolted Joints.*** Type C specimens were used exclusively in this series. The tensions in the test bolts were approximately 45 kips per bolt. Except as noted, all bolt holes were drilled.

The group of tests with mill-scale surfaces and drilled holes had an average coefficient of friction at the first major slip of 0.36. The results of these tests are given in Table II. The average coefficient of friction was 0.34 for the specimens with subpunched and reamed holes. Only slightly lower coefficients of friction at the first major slip were found for plates with subpunched and reamed holes than for drilled holes. This difference was not considered great enough to be significant.

The three sandblasted specimens gave the highest

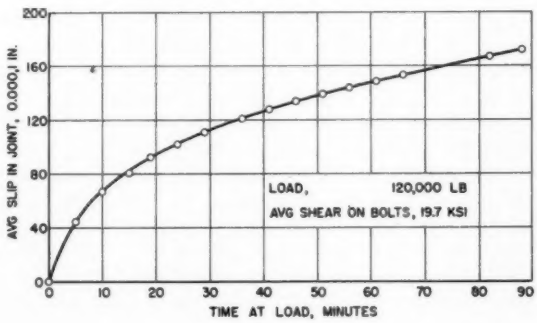


FIG. 2. TIME-SLIP RELATIONSHIP OF VARNISHED SPECIMEN UNDER CONSTANT LOAD

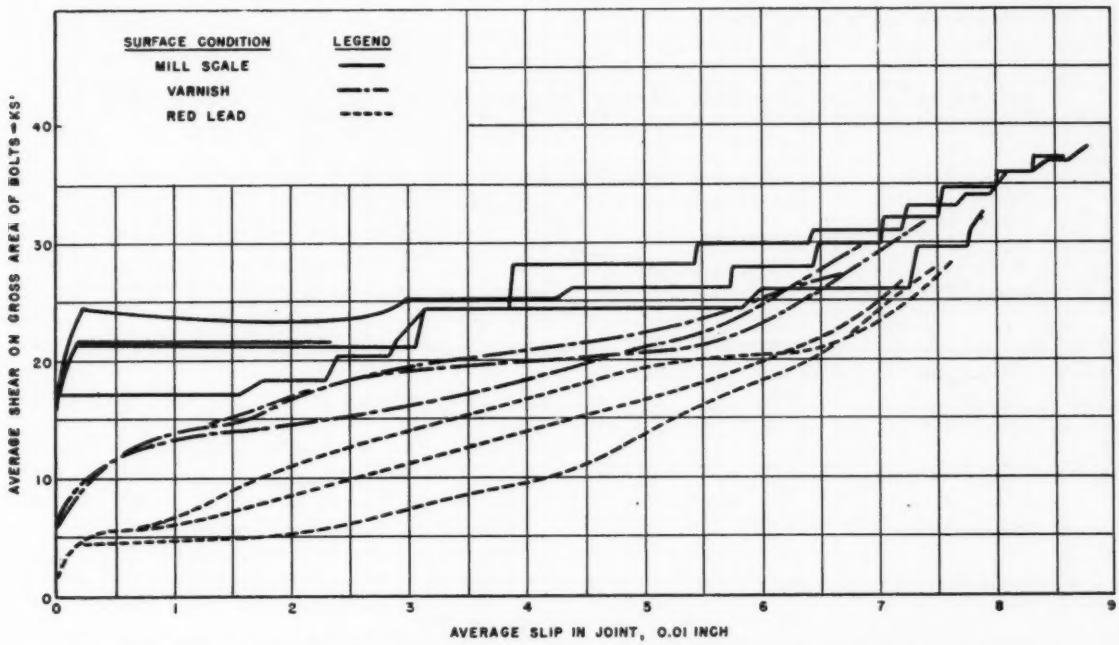


FIG. 3. COMPARISON OF SLIP CHARACTERISTICS WITH MILL-SCALE, VARNISHED, AND RED-LEADED FAYING SURFACES

average coefficient of friction obtained. The values for the three tests were 0.44, 0.38, and 0.59, for an average of 0.47. The highest value obtained for Type C specimens which were not sandblasted was 0.42 for specimen Nos. 14 and 38. Sandblasting the faying surfaces effectively increased the coefficient of friction at the first major slip. Since the surface of a sandblasted specimen was much rougher than the surface of a mill-scale specimen, the higher coefficient could probably be attributed to a greater degree of mechanical interlock of the faying surfaces.

The manner in which slip occurred in the joints with mill-scale faying surfaces and either drilled or subpunched and reamed holes and the joints with sandblasted surfaces was the same. When load was applied to a specimen, there was at first no significant amount of slip in the joint. As the load was increased, a very small amount of slip and elastic deformation was indicated by the gages. A load was eventually reached at which the shear between the plates overcame the frictional resistance to slip. The plates then slipped with extreme rapidity. The first large slip is referred to as the first major slip.

Specimens with varnish or red-lead paint on the faying surfaces had a quite different relationship between load and slip from that of the tests previously described. Instead of slipping very rapidly and in comparatively large amounts at various increments of load, the joint slipped slowly and continuously.

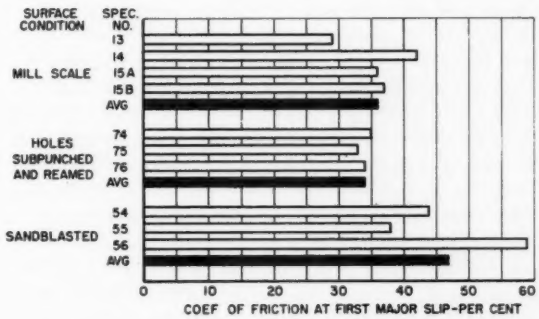


FIG. 4. EFFECT OF SURFACE CONDITIONS UPON NOMINAL COEFFICIENT OF FRICTION AT FIRST MAJOR SLIP

Loads were applied to these specimens and held constant while slip progressed. The joints slipped slowly, the rate of slip decreasing with time. An illustration of the time-slip relationship under constant load is given in Fig. 2. The data for this curve were taken from specimen No. 52; the load for these particular readings was 120,000 lb, and the average shear on the bolts, 19.7 ksi.

The different manner in which slip occurred in the joints with varnished and red-leaded faying surfaces as compared to those with mill-scale or sandblasted faying surfaces may be seen in Fig. 3. This figure shows the greatly reduced resistance to slip for which

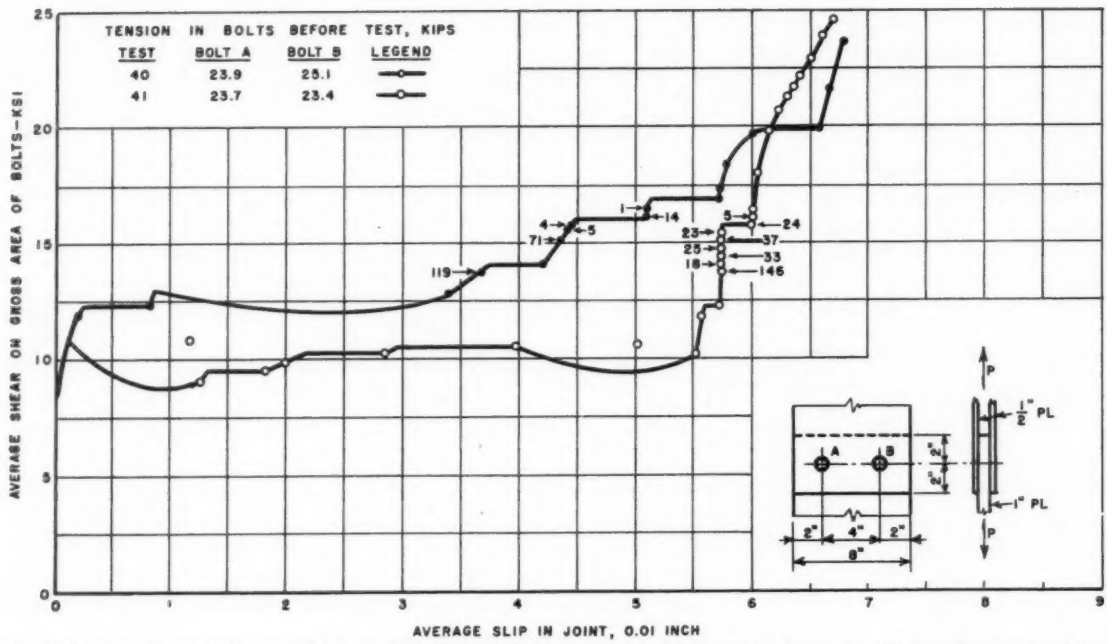


FIG. 5. COMPARISON OF NOMINAL SHEAR IN BOLTS AND AVERAGE SLIP OF JOINT FOR SPECIMENS UNDER SUSTAINED LOAD

Note: Numbers by test points indicate time load in hours.

these coatings were responsible. Specimens with red-lead paint on the faying surfaces mobilized even less resistance to slip than did those with varnish. The coatings appeared to act as viscous fluids which lubricated the faying areas. Because there was no definite point of first major slip and because the amount of slip was dependent upon the time at load, even for low loads, coefficients of friction for the specimens with painted faying surfaces could not rationally be computed.

The specimens with varnish and red-lead paint might have slipped into full bearing at even lower shears than those shown by these tests if the loads had been sustained for days or weeks instead of minutes. There is no advantage in using high-strength bolts and high bolt tensions in structural joints to prevent slip if the surface conditions are such that the joint slips into bearing anyway. These tests indicated that, if prevention of slip is a criterion of design, varnish or red-lead paint should not be used on the faying surfaces.

Figure 4 is a bar graph which compares the average coefficients of friction at the first major slip for the specimens with mill-scale and sandblasted faying surfaces and for the specimens with drilled and with subpunched and reamed holes. The coefficients of friction for joints with mill-scale faying surfaces were approximately of the same magnitude, regardless of whether the holes were drilled or subpunched and reamed. Joints with sandblasted faying surfaces tended to develop somewhat higher coefficients of friction than those with mill-scale faying.

*2. **Effect of Sustained Loads upon Slip of Bolted Joints.*** Two tests were run to determine whether or not a sustained load would cause a different load-slip relationship than that found by tests with short-time loading. The load in these tests was held constant at various levels for periods of time indicated by numbers next to the test points in Fig. 5. Slip did not occur during any period of constant load though the load was held constant for as long as 146 hours. The specimens with mill-scale surfaces subjected to sustained loads slipped in the same manner as they did under short-time loadings. Further tests under sustained load are necessary to substantiate this finding.

Summary.

Bolted joints with various surface conditions on the faying areas were tested. The highest value of the coefficient of friction found for mill-scale plates with drilled holes was 0.45, and the lowest was 0.29. The coefficients for plates with subpunched and reamed holes were slightly lower on the average, and sandblasted faying surfaces gave an appreciably higher average coefficient. Specimens with varnish or red-lead paint on the faying surfaces exhibited very little resistance to slip. Accordingly, it seems that these coatings should not be used on the faying surfaces of a joint if prevention of slip is a criterion of design.

The Importance of Engineering Research to Education

F. BURT FARQUHARSON
Director of the Engineering Experiment Station

FOR THE PURPOSE of this brief paper, it will be convenient, but not wholly accurate, to assume that a research program properly integrated with the normal educational process will at the same time serve the best interests of industry.

"The desirability of research in colleges and universities is generally recognized, but the idea that research is an essential feature of a true university is not always accepted." This statement in a recent paper by Thomas K. Sherwood, Dean of Engineering at the Massachusetts Institute of Technology,* contains sufficient meat for provocative and rewarding discussion far beyond our present scope, which will cover only a few salient aspects of the place of research in our engineering institutions with special emphasis on the problems of the Pacific Northwest.

It should not be forgotten that the Northwest is still very close to its pioneer origins and is only just now coming of age. This passing of a milestone, as important to an institution as to an individual, is marked by the fact that all of us are now engaged in research and instruction at the graduate level in addition to the undergraduate activities which six years ago almost completely preoccupied us. One might guess that in many instances the situation is parallel to that of a high school which has shouldered the added responsibility of a junior college without significant addition to its high school staff.

The responsibilities of the *true university,* mentioned by Dean Sherwood, number among the most important that of adding continuously to the sum-total of knowledge embraced in the several disciplines comprising the institution. Significant addition to knowledge is not made solely from however diligent a collection of facts and skillful presentation before classes; nor from patient schooling in the performance of intricate tasks of basic importance in the various branches of engineering. Do not misunderstand; these functions are important, but optimum performance requires that the instructor have access to the very latest thought in his field and in addition possess the means of continuing his broad education in the basic fields of science out of which his professional specialization has grown and from which it must gain much of its continued nourishment if it is to live and expand.

The problems involved here are vast and vexing especially in times of transfer to higher levels of activity. Of special difficulty is the need for integrating into the teaching staff individuals of academic training broader than the previous norm. The gap between these two groups must be bridged and the process of education extended in both directions. A common fallacy lies in the assumption that the task of the instructor is limited to the education of the student body. He has a still higher obligation to educate himself and, as a part of the corporate faculty, to assume his full responsibility in the continued education of his peers. This last and most important aspect of education is achieved through skillfully operated seminars, joint research efforts involving one or more departments, and participation in the activities of professional societies.

These several functions of faculty education have as their chief objective the effective instruction of our students, and may be implemented in many ways. It is the writer's belief, however, that this goal may be best realized through a well-integrated program of research which involves the whole faculty, the total body of graduate students and, to a limited extent, certain categories of senior students.

With the bold statement of so ambitious a goal, a brief outline of the predominant features of such a venture may be examined. It is probably axiomatic that few instructors can become authorities in all aspects of the field in which they teach. But much zest and color of authority can be brought to their lectures if they are actively engaged in an attempt to extend the frontiers of knowledge in some phase of their special interest. This activity may be in the field or laboratory and may in some cases be mildly associated with a consulting practice. In all cases active association with the professional societies involved is mandatory, with due participation in professional committee assignments and the preparation of technical papers and discussions. As a fully active professional worker, an instructor may take part in the development of new ideas and techniques. As a working member of a professional society or national

* *Chemical Engineering News,* American Chemical Society, Vol. 28, page 456, Feb. 13, 1950.

or regional committee, he may have a hand in the preparation of codes of practice growing out of his and others' efforts in a common field. And finally, in the performance of his chief educational function, as he stands before his class, he is in a position to speak with authority as one fresh from the very latest practice in his field.

In contrast, the individual who has no working contact with his profession may often find himself teaching from a text which is already outdated, and with no urge to scrap his outmoded lecture notes which offer such an easy approach to his daily task. There is, without doubt, room in the engineering college for a few whose function is purely interpretive: who devote themselves wholly to the delineation of intricate techniques or make a major contribution through the interpretation of the technical present in terms of its historical past. There is too, the problem of purely service courses, the teaching of which involve serious problems of management in terms of well-integrated assignment which will permit the younger instructor, who is generally saddled with these tasks, to grow professionally.

Mention has been made of the instructor in his laboratory, but one should not hold the picture of a lone individual burning midnight oil continuously (although there will doubtless be plenty of that). The true picture should rather show a joint laboratory or field effort in which the instructor provides the guidance and supervision and graduate students constitute the balance of the staff.

In these days of growing interdependence of the various divisions of engineering, it will be profitable to consider a more broadly integrated type of research activity into which may be brought faculty supervisors and workers from more than one department. It may even be desirable in such an effort to cross the boundaries of engineering into such fields as physics, chemistry, and mathematics. The Environmental Research Laboratory at the University of Washington is an example of broad cooperation between the College of Engineering, the Department of Meteorology, and the Department of Public Health and Preventive Medicine. This group is contributing to the education of students from all three divisions and is presently engaged in an air pollution survey for the City of Seattle, a study of the toxic effects of certain dusts used in the fruit orchards of the state, and a survey of the pollution hazards in a number of industries. It has also recently been granted a contract from the Air Service covering an investigation of the toxicity of certain new jet fuels. This joint effort is financed by the various sponsors and provides as its principal by-product a high level of graduate education and training.

Since this example is admittedly over-simplified, let us consider a more detailed account of a typical transition into the field of higher educational effort. Let it be assumed that the institution involved is well equipped with an eager and well-grounded upperclass undergraduate student body. The pressure of the times and the example of more mature institutions in the older parts of the country have forced the announcement that, as of a certain date, the institution will accept graduate students. Among the faculty on this end of the campus the doctor's degree is practically unknown, and master's degrees are not numerous, although there is a very healthy proportion of professional degrees denoting a certain level of off-campus experience on the part of the faculty.

The simple solution for this problem calls for the devising of certain additional courses which are given graduate numbers and are assigned for development to the most available members of the various departments. Since the situation may be assumed to have arisen during the past five years, the problem of enticing numerous G.I.'s into a prolonged educational effort is not serious and the opportunity soon arises for additions to the faculty.

The success of this new venture into the field of graduate work hinges now on the decisions made in the earlier phases of the expansion in staff. The past experience of the institution has not embraced any very elaborate research efforts because of shortage of funds and the pioneer nature of local industry. The proper assumption of the new responsibilities requires the hiring of a type of man different from those hitherto sought. These men should have been through the graduate mill and a fair proportion should possess a doctor's degree.

In this transition period a broad type of leadership is necessary if serious internal dissension is to be avoided, since the bringing in of younger men of superior educational attainment can be seriously disruptive to morale.

To meet this problem, experience has shown that the transition to an integrated graduate effort can be greatly stimulated by specific research tasks in which the leadership is made up of a combination of the old and the new blood, and the graduate students assume the major portion of the work load. If the research is sponsored by some outside agency the necessity for a respectable showing adds zest and interest since assuredly the results will be closely and critically scrutinized.

The most important dividend from this attempt to integrate education and research arises from the feeling of accomplishment on the part of the research team which is speedily translated into a more lively and provocative relationship between instructor and student at all levels.

Professors Retire After Long Careers

C. W. Harris

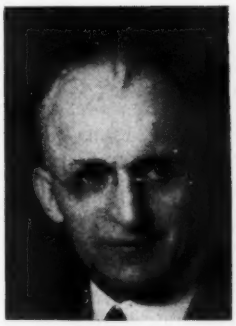
Charles W. Harris, Professor of Hydraulic Engineering, and Frederick K. Kirsten, Research Professor of Aeronautical Engineering retired from active duties at the close of the school year. Both have been associated for more than 35 years with the College of Engineering during its major development.

Professor Harris, who was awarded the signal honor of being named "Alumnus summa laude dignatus" of the University a year ago, received his degree of B.S. in C.E. in 1903. Two years later he received his C.E. degree at Cornell University. During 1905-6 he worked as assistant location engineer for the Milwaukee R. R. during the preliminary location of the Snoqualmie Pass route, and was office engineer for the Copper River and Northwest R. R. at the time and in the setting described by Rex Beach in *The Iron Trail.*

In 1906 he returned to Seattle to serve as a faculty member of his alma mater until his recent retirement. He acted as head of the Department of Civil Engineering 1917-1920, and was made a full professor in 1924.

In addition to his teaching duties, Professor Harris has been concerned with the design and construction of numerous hydraulic projects, including power development, dams, and diking and drainage (such as the Longview project), and is noted for his design of a revolutionary type of fishway which has largely superseded the conventional type. His publications include a number of short articles and Experiment Station bulletins on hydraulics. His paper before the ASCE in 1949, published in the *Transactions* of 1950, on "An Engineering Concept of Flow in Pipes," was the culmination of twenty years' study of this subject.

Professor Harris is a member of Tau Beta Pi, an Alpha Chapter (Cornell) member of Sigma Xi, and a life member of ASCE. For some twenty years he served as secretary of the Research Society of the University of Washington. His hobby for many years has been building boats. His latest model, a 54-ft power schooner was put into commission in 1949.



F. K. Kirsten

Professor Kirsten, who was born in Saxony, Germany, came to the United States in 1903 and was naturalized in 1911. He received his B.S. in E.E. from the University of Washington in 1909 and his degree of E.E. in 1913. During 1914 he served as equipment engineer at MIT on the design of a new building group.

In 1915 he joined the College of Engineering staff as assistant professor of electrical engineering, and in 1923 was made a full professor. When the Department of Aeronautical Engineering was set up in 1928 he was transferred to that department, where he has been distinguished as teacher and designer. During World War I while on leave from the University, he acted as Chief Engineer of the American Nitrogen Products Co. of Seattle.

From 1921-40 Professor Kirsten was vice-president of the Kirsten-Boeing Engineering Corporation, and he has been president of the Kirsten Research Corporation since 1941.

As a result of Professor Kirsten's work in the field of aeronautics prior to 1929, the Daniel Guggenheim Fund for the Promotion of Aeronautics provided for the construction of Guggenheim Hall. Construction of the F. K. Kirsten Wind Tunnel, which started operations in 1937, was also largely due to his efforts, and he was actively concerned with the planning and design of both of these structures.

Professor Kirsten is the author of *Transmission Line Design,* Part I, "Mechanical Features" (1916), Part II, "Electrical Features," with E. A. Loew (1925), and Part III, "A 500-Mile Transmission Line," with C. M. Briggs (1927). Following his entrance into the field of aeronautics his chief interest was centered in the study of the application of cycloidal propulsion. Numerous publications have appeared on this subject, the most recent being UWAL Report No. 322 (1950) on "The Cycloidal Propeller in Marine Application."

Professor Kirsten is a member of Sigma Xi, Tau Beta Pi, AIEE, ASME, and the Research Society of the University of Washington.

Engineering Research Dividends

Recent theses for advanced degrees, which were submitted as reports on Engineering Experiment Station research projects, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station.

LEE, C. Y., "Experimental Investigation of Dielectric Properties of Lucite as a Function of Temperature and Frequency." M.S. in Electrical Engineering, 1949.

In the investigation of high-frequency dielectric heating, it is of primary importance to know the dielectric properties of the substances undergoing such heating. Lucite was chosen in this investigation because of its homogeneous structure, high melting point, and good workability. A Boonton Q-meter type 160A with a small external oven was used in the experiment. The heat was generated by uniformly spaced heating elements placed on the walls of the oven. The variation of dielectric constant and power factor of Lucite was obtained for a frequency range of 0.85 to 25 megacycles and a temperature range of 25° to 120° C. Problems of lead resistance and inductance of the air gaps between the sample and plates, of stray capacitances, and of the uniformity of temperature throughout the sample were encountered, but all these difficulties were successfully overcome. The experimental results were in disagreement with Debye's theory for gases and liquids, but with some suitable modifications there were qualitative agreements. A discussion on this subject is included in a separate report. As an extension to this investigation, it is suggested that the frequency range may definitely be pushed up to include wave guide frequencies, and it would be of interest to investigate the low-temperature dielectric behavior of Lucite.

HARLAND, J. W., "The Effect of Lightening Holes and End Connections on the Strength and Ductility of Aluminum Angles." M.S. in Civil Engineering, 1949.

This thesis presents a report on an experimental investigation to determine the effect of lightening holes and end connections on the strength and ductility of aluminum alloy angles. The results of the tests indicated that the number of lightening holes had very little effect on the tensile strength. However, an increase in the number of lightening holes from two to seventeen more than doubled the elongation. The effect of the lightening holes could be overshadowed by the effect of the end connections. If the end connections were made both eccentric and flexible, a stress concentration due to bending resulted in the end connection. This stress concentration caused failure before the main part of the specimen was stressed enough for ductile yielding. As a result, both strength and ductility were reduced.

SANDHOLTZ, W. A., "Synthesis of Pure Fluorapatite."* M.S. in Chemical Engineering, 1949.

Reliable proof is offered in the literature to show that the commercial phosphates are not uniform and seldom of the theoretical formula $Ca_3(PO_4)_2$. In recognition of this fact, a relatively simple procedure developed by MacIntire, et al., was followed here with slight modification. Fusion was tried in both molybdenum and platinum vessels. As a result of the reactivity of hot molybdenum, it was not possible to reproduce a truly pure apatite by fusion as found by x-ray diffraction. By comparison, use of platinum was much less complicated than that of molybdenum; furthermore, the possibility of contamination from the container was eliminated. However, the author is particularly attracted to the use of rhodium in the synthesis, because rhodium possesses all the advantage of platinum and, in addition, a 200° C higher melting point. The filtration of the gelatinous precipitate of tricalcium phosphate hydrate, obtained during the process, was very slow, and it was very difficult to wash the precipitate. Even when filter aid like quartz was added, the precipitate was still hard to manage so far as the filtration was concerned; moreover, the final separation of quartz from the precipitate engendered heavy loss of product. This procedure was, therefore, abandoned in favor of washing by repeated centrifugation and decantation which produced with relative ease an excellent product of nearly theoretical yield.

* The work reported here was done as a part of the project on "Solubilization and Reversion Studies in Thermally-Treated Phosphate."

Notes and Comments

ENGINEERS IN THE NEWS

G. S. SMITH, Professor of Electrical Engineering read a paper on "Climatology as an Aid in Heat-Pump Design," at the meeting of the ASHVE July 2-4 at Portland.

A. V. EASTMAN, Professor and Executive Officer of Electrical Engineering, attended the board meeting of the IRE of which he is Pacific Regional Director, held in New York, May 9, and made a round of inspections of sections located in Salt Lake City (May 7), Inyokern Navy Base, China Lake, California (May 11), and Hawaii (May 23-27). On June 20-22 he attended the Seventh Regional Conference, held at Seattle, and will be present at the West Coast IRE Convention at San Francisco August 23-25.

R. G. HENNES, Professor of Civil Engineering, has been appointed chairman of Section X—Groundwater Problems, by the U.S. National Council of Soil Mechanics and Foundation Engineering. He will also represent the University of Washington on the recently established Washington State Council of Highway Research. As recognition of his work in earthquake investigation, Professor Hennes has been elected to membership in the Earthquake Engineering Research Institute.

L. J. LEWIS, Associate Professor of Electrical Engineering will present a paper, "Traveling Wave Relations Applicable to Power-System Fault Locators," at the Pacific General Meeting of the American Institute of Electrical Engineers, to be held in Portland, Oregon, August 20-23, 1951. Dr. Lewis is an electrical consultant to the Bonneville Power Administration.

The article "The Importance of Research in Engineering Education" by **F. B. FARQUHARSON,** Director of the Engineering Experiment Station, which appears in this issue of *The Trend,* was presented before the Northwest Sectional Meeting of the ASEE at Moscow, Idaho, May 5. As chairman of the Northwest group of ECRC, Professor Farquharson was authorized to present a petition for formal recognition of the group as the Northwest Division of ECRC.

R. A. HECHTMAN, Associate Professor of Structural Research, attended the meeting of Subcommittee E of the Column Research Council, May 10-11, to discuss progress and future work on his project on lateral buckling of beams. He met with representatives of the Committee on Ship Steel, Navy Department, May 15, where he presented the report of the Ship Structures Research project and discussed plans for future tests. May 16 he attended the meeting of the Society for Experimental Stress Analysis in New York.

W. W. PHILBRICK, Assistant Director of the Engineering Experiment Station, made a tour of investigation March 17-30 in the interests of the Environmental Research Laboratory. He consulted with Dr. Robert Kehoe of the Kettering Laboratory, University of Cincinnati, and Professor Philip Drinker, Director of Environmental Research in the Harvard School of Public Health, and met representatives of several large chemical companies in the East. Professor Philbrick presented a paper on "Electronic Recording of Student Reaction" before the ASEE meeting at East Lansing, Michigan, June 26.

R. M. ROSENBERG, Associate Professor of Aeronautical Engineering attended the meeting of the First U. S. National Congress of Applied Mechanics at Chicago, June 11-16 and read a paper co-authored by Michael Golomb of Purdue University. He then went on to the West Coast Conference of the Applied Mechanics Division of ASME held at Stanford June 22-23 where he presented a second paper.

H. C. MARTIN, Associate Professor of Aeronautical Engineering also read papers at the Chicago and Stanford meetings and attended the Annual Summer Meeting of the Institute of the Aeronautical Sciences at Los Angeles, where he presented a paper "On the Deflection of Swept Cantilevered Surfaces" co-authored by **H. J. GURSAHANEY,** Research Fellow in the Engineering Experiment Station.

R. G. JOPPA, Instructor in Aeronautical Engineering and Research Engineer of the UWAL, presented a paper on "The Contribution of the University of Washington Aeronautical Laboratories to the Educational Program," before the ASEE meeting at East Lansing, June 24-29.

L. B. COOPER, Assistant Professor of Mechanical Engineering, is on emergency leave from the University to work on power design with the Bechtel Corporation at San Francisco.

H. M. HENDRICKSON, Associate Professor of Mechanical Engineering, visited Wright-Patterson Air Base and a number of eastern laboratories in order to collect information on the design, construction, and operation of gassing chambers, in connection with the project on Rocket Exhaust Studies sponsored by the Air Materiel Command. Professor Hendrickson is engineering consultant for this project which is being conducted by the Environmental Research Laboratory.

PRAGER LECTURES ON ELASTICITY TO BE PUBLISHED

Engineering Experiment Station Bulletin No. 119, which will be issued this summer, will contain the Walker-Ames lectures delivered by Dr. William Prager at the University of Washington under the title of "The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis."

Dr. Prager held a Walker-Ames professorship April 26-May 29, 1950. During the later part of this period he conducted five seminar meetings devoted to practical aspects of the method of stress analysis presented in his lectures. An additional special lecture on plasticity was printed in *The Trend* issue of January, 1951, under the title, "What Does the Theory of Plasticity Offer to the Designer?"

Dr. Prager is the distinguished chairman of the Graduate Division of Applied Mathematics at Brown University. He is the author of numerous monographs in German, French, and English, and is a frequent contributor to the *Quarterly of Applied Mathematics* of which he has been managing editor since 1947.

NEW REPRINTS

Reprint No. 39. "An Engineering Concept of Flow in Pipes," C. W. Harris, *Transactions,* ASCE, 1950.

Reprint No. 40. "Rotating Electrode in Manual Metal Arc Welding," G. S. Schaller, *Weld. Jour. Res. Supp.,* Jan., 1951.

Reprint No. 41. "A Note on Control Area," T. M. Stout, *Jour. App. Phys.,* Nov., 1950.

Reprint No. 42. "Clarification of Equations for Simple Forced Vibration," B. D. Mills, Jr., *Jour. Eng. Educ.,* Dec., 1950.

Reprint No. 43. "High Temperature Porcelain Enamel for Tungsten," J. C. Horsfall, *Bull. Am. Cer. Soc.,* Sept. 15, 1950.

Reprint No. 44. "A Chromatographic Study of Sulfite Waste Liquor Sugars," P. K. Mulvany, H. D. Agar, Q. P. Peniston, J. L. McCarthy, *Jour. Am. Chem. Soc.,* Mar., 1951.

Reprint No. 45. "Climatology as an Aid in Heat Pump Design," G. S. Smith, ASHVE Journal Section, *Heating, Piping, and Air Conditioning,* Jan., 1951.

PRODUCTION OF OZONE WITH REFRIGERATED ANODES

(Continued from page 16)

refrigerated anodes, ozone energy yields up to 24 g/kwhr, and concentrations up to 58 weight per cent ozone have been obtained.

2. Ozone concentration is a function of the anode temperature. Lowering the anode temperature increases the ozone concentration and the energy yields.

3. At constant anode temperature, increasing the current density increases the ozone concentrations and energy yields.

ACKNOWLEDGMENTS

We are indebted to Mr. Ray Newbury for skillful construction of the glass to platinum seal of Cell No. 1. Mr. Newbury also performed all of the other glass-blowing work connected with this project. The Owens-Corning Fiberglas Corporation supplied the glass cloth.

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HIGH-FREQUENCY LOSSES IN ELECTRIC CONDUIT

(Continued from page 22)

Conclusion

1. The curves shown indicate the trend at the higher frequencies, but the only accurate method of establishing ratings is to employ a variable-frequency current source of large output and make temperature measurements.

2. It is not practicable to use standard 60-cycle construction at the higher frequencies, particularly for carrying large currents. It is better to place the conductors in nonmetallic conduit or raceway for medium frequencies, but at still higher frequencies it would probably be desirable to use concentric transmission line construction developed by the radio industry.

3. Because of the higher losses at high frequencies, the generating equipment should be placed close to the load.

4. Although the code now specifies no upper frequency limit for standard construction, such a limit exists and should be recognized.

PUBLICATIONS

of the

ENGINERING EXPERIMENT STATION

UNIVERSITY OF WASHINGTON

Requests for copies of publications should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

BULLETINS

48. The Influence of Pipe Thickness on Re-Entrant Intake Losses. Charles William Harris. 35 pp. 1928.
55. Vacuum-Tube Control for Electric Wind-Tunnel Balances. Fred Scoville Eastman. 20 pp. 1931.
56. Constant Flow Characteristic of the Plane Orifice in Proximity to Side Walls. Charles William Harris. 18 pp. 1931.
58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
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61. Hydraulic Flow Characteristics of a Square-Edged Intake. Charles William Harris. 21 pp. 1932.
67. The Doherty Washer Cooler. Sybren Ruurd Tymstra. 61 pp. 1932.
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78. Hydroelectric Power in Washington. Part III, A Brief on Proposed Grand Coulee Dams. Carl Edward Magnusson. 32 pp. 1935.
79. Cycloidal Propulsion in Air. Part I, Cycloidal Propulsion Theory; Part II, Cycloidal Propeller Development at the University of Washington. Frederick Kurt Kirsten. 87 pp. 1935.
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90. Hydroelectric Power in Washington. Part IV, Regional Electric-Power Transmission. The Grid System. Carl Edward Magnusson. 51 pp. 1936.
91. The Analysis and Control of Landslides. Robert Graham Hennes. 57 pp. 1936.
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93. Electric Power Markets in Washington. Part I, Electric Heating of Residences. Carl Edward Magnusson. 40 pp. 1937.
94. Evaporative and Surface Cooling. George Samuel Wilson and William Lyle Dudley. 18 pp. 1937.
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97. Strength of Concrete for Mixes of Various Proportions. Ira Leonard Collier. 28 pp. 1938.
98. Geology and Its Relation to the Occurrence of Oil in Washington. Charles Edwin Weaver. 16 pp. 1938.
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100. Modernization of a Transit System. Factors that Determine the Choice of a Vehicle. George Lisle Hoard. 36 pp. 1940.
101. Buckling Criteria and Design of Two-Story Columns. Sergius I. Sergev. 48 pp. 1940.
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Prof. S. Sergev